TREATISE

~~Edward~~ OF THE ~~Crofton~~

Coll Carlow

Animal Oeconomy.

The Second Edition, with Additions.

BY

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PREFACE.

IN the following Treatiſe I have avoided Hypotheſes, *and explained the Laws which obtain in human Bodies, by Reaſon and Experiments.* Hypotheſes, *of whatever Nature, are not to be admitted in Philoſophy. Now whatever is not deduced from the* Phænomena, *is to be called an* Hypotheſis.

Harvey *from Experiments and Obſervations traced out the Circular Motion of the Blood. After him* Lower *made ſome farther Diſcoveries con-*

cerning that Motion, and the Causes by which it may be disturbed. After these great Men, the Knowledge of the Animal Œconomy *received no very considerable Improvement, till Sir* Isaac Newton *discovered the Causes of* Muscular Motion, *and* Secretion; *and likewise furnished Materials for explaining* Digestion, Nutrition, *and* Respiration. *To Him I am chiefly indebted for what I have delivered on those Heads.*

In this second Edition *I have added a* Section *concerning the* Effects of various Fluids, of Age, of different Kinds of Weather, and of Exercise, on animal Fibres.

A

TREATISE

OF THE

Animal Oeconomy.

IN this Treatise I shall give an Account of the principal Parts of the *Animal Oeconomy*; which I shall explain, not by Hypotheses, but by Reason and Experiments. The Parts I shall treat of, are *Muscular Motion*, *the Motion of the Blood*, *Re-*

spiration, Digestion, Nutrition, Secretion, the Discharges of Human Bodies, and the Effects of various Fluids, of Age, of different Kinds of Weather, and of Exercise, on Animal Fibres.

In order to explain *the Motion of the Blood*, I shall premise an Account of *the Motion of Fluids thro' Cylindrical Pipes*, and prove the Properties of that Motion by Experiments.

SECTION I.

Of the Motion of Fluids through Cylindrical Pipes.

PROPOSITION I.

IF a given Fluid be moved through a Cylindrical Pipe made of a given Sort of Matter, by a Force acting constantly

stantly and uniformly during the whole Time of the Motion; its Velocity, setting aside the Resistance of the Air, will be in a Ratio compounded of the subduplicate Ratio of the moving Force directly, and of the subduplicate Ratios of the Diameter and Length of the Pipe taken together inversly. If F *denote the moving Force,* D *and* L *the Diameter and Length of the Pipe, and* V *the Velocity with which the Fluid runs through the Pipe; then* V *will be proportional to* $\sqrt{\frac{F}{DL}}$.

For the whole Motion of the Fluid flowing through the Pipe will, like all other Motions, be measured by the Quantity of Matter moved and its Velocity taken together. But the Quantity of Matter moved, is in a Ratio compounded of the Ratios of the Quantity of Matter or Weight of Fluid contained in the Pipe, of the Velocity wherewith the

the Fluid flows through the Pipe, and of the Time of the Motion. For the Quantity of Matter or Weight of Fluid contained in the Pipe, is opposed to the moving Force during the whole Time of its Action, and must be moved by it for every indefinitely short Cylinder of Fluid discharged by the Pipe; that is, for every physical Point in the Length of another Cylindrical Pipe of an equal Diameter with that through which the Fluid flows, and of such a Length as that it can just contain the Quantity of Fluid discharged in the Time of the Motion; which Length being as the Velocity of the Fluid flowing through the Pipe and the Time of the Motion taken together, the Quantity of Matter moved will be in a Ratio compounded of the Ratios of the Quantity of Matter or Weight of Fluid contained in the Pipe, of the Velocity

locity wherewith it flows through the Pipe, and of the Time of the Motion. And the whole Motion, which is as the Quantity of Matter moved and its Velocity taken together, will be in a Ratio compounded of the simple Ratios of the Quantity of Matter or Weight of Fluid contained in the Pipe, and of the Time of the Motion; and of the duplicate Ratio of the Velocity: Therefore, putting T for the Time of the Motion, and Q for the Quantity of Matter or Weight of Fluid contained in the Pipe; the whole Motion will be as QTV^2.

Setting aside the Resistance of the Air, this Motion would be proportional to the moving Force and Time of its acting taken together, that is, QTV^2 would be proportional to FT, if the internal Surface of the Pipe, by Friction, or Attraction, or both, did not act continually

upon

upon the Fluid moving through it, and cause a Change in its Motion proportional to the Efficacy wherewith it acts; which Efficacy in a Pipe made of a given Sort of Matter, is measured by the Ratio of the internal Surface of the Pipe to the Quantity of Fluid contained in it; that is, by D L applied to Q. And by Consequence $\frac{QTV \cdot DL}{Q}$ will be proportional to F T: Whence V will be proportional to $\sqrt{\frac{F}{DL}}$.

Cor. 1. If the moving Force and Diameter of the Pipe, be both given, or be proportional to each other; the Velocity, setting aside the Resistance of the Air, will be in the inverse subduplicate Ratio of the Length of the Pipe. If F and D be given, or if F be as D; V will be as $\frac{1}{\sqrt{L}}$.

Cor.

Cor. 2. If the moving Force be as the Quantity of Fluid contained in the Pipe; the Velocity, setting aside the Resistance of the Air, will be in the subduplicate Ratio of the Diameter of the Pipe and Density of the Fluid taken together. Putting Δ for the Density of the Fluid, if F be as $D^2 L \Delta$; then V will be as $\sqrt{D \Delta}$.

Cor. 3. If the moving Force be as the Quantity of Fluid contained in the Pipe, and the Density of the Fluid be given; the Velocity, setting aside the Resistance of the Air, will be in the subduplicate Ratio of the Diameter of the Pipe. If F be as $D^2 L \Delta$, and Δ be given; then V will be as $\sqrt{D}$.

Cor. 4. If the moving Force be proportional to the Square of the Diameter of the Pipe, and the Length

Length of the Pipe be given, or if the moving Force be as the Capacity of the Pipe; the Velocity, setting aside the Resistance of the Air, will be in the subduplicate Ratio of the Diameter of the Pipe. If F be as D^2, and L be given, or F be as $D^2 L$; then V will be as $\sqrt{D}$.

Cor. 5. If the moving Force be as the Square of the Diameter of the Pipe; the Velocity, setting aside the Resistance of the Air, will be in a Ratio compounded of the subduplicate Ratio of the Diameter of the Pipe directly, and of the subduplicate Ratio of its Length inversly. If F be as D^2; then will V be as $\sqrt{\frac{D}{L}}$.

Cor. 6. If the moving Force be as the Capacity of the Pipe, and the Diameter of the Pipe be in the sub-

ſubduplicate Ratio of its Length; the Velocity, ſetting aſide the Reſiſtance of the Air, will be in the ſubquadruplicate Ratio of the Length of the Pipe. If F be as D^2L, and D be as $\surd L$; then will V be as $L^{\frac{1}{4}}$.

Cor. 7. The moving Force, ſetting aſide the Reſiſtance of the Air, will be in a Ratio compounded of the duplicate Ratio of the Velocity, and of the ſimple Ratios of the Diameter and Length of the Pipe. F will be as V^2DL.

Proof by Experiments.

TO prove the Truth of this Propoſition by Experiments, I procured ſeveral Cylindrical Pipes of Braſs, of different Diameters

and Lengths; each of which Pipes had one End fitted to ſcrew into the Side of a Veſſel filled with Water, at three different Diſtances from its Top, namely, at the Diſtances of one Foot, two Feet, and four Feet. The Veſſel made for theſe Experiments, was a ſquare Wooden Veſſel ſomething above four Feet in Depth, and nine Inches of a *London* Foot in its internal Length and Breadth.

Before I give an Account of the Experiments, it will be neceſſary to ſhew how to meaſure the moving Forces and Velocities of Water, flowing through Cylindrical Pipes ſcrewed into the Side of a Veſſel filled with Water.

To meaſure the moving Force of Water flowing through a Cylindrical Pipe, ſcrew'd into the Side of a Veſſel filled with Water; we muſt know the Area of the Top of the Water

Water in the Veſſel, the Area of the Orifice of the Pipe, the perpendicular Diſtance of the Place of the Pipe's Inſertion into the Side of the Veſſel from the Top of the Water, and the Situation of the Pipe with reſpect to the Horizon.

Let the Area of the Top or upper Surface of the Water in the Veſſel be called A, the Area of a Hole made in the Bottom or Side of the Veſſel be called a, and the perpendicular Diſtance of the Hole or Place of Inſertion of the Pipe from the Top of the Water be called H; and then, by *prop.* 36. *lib.* 2. *Princip. Newton.* the Velocity of the Water flowing out of the Hole, ſetting aſide the Reſiſtance of the Air, will be equal to the Velocity which a heavy Body would acquire in falling perpendicularly and without Reſiſtance thro' the Space $\frac{A^2H}{A^2-a^2}$. And,

by the second *Corollary* of the same *Proposition*, the Force generating the whole Motion of the effluent Water, will be equal to the Weight of a Cylinder of Water, whose Base is $\frac{12}{17}$ Parts of the Area of the Hole, or a, and whose Height is $\frac{2A^2H}{A^2 - a^2}$. If the Area of the Hole, be exceeding small when compared with the Area of the upper Surface of the Water, that is, if a be exceeding small when compared with A; the Height $\frac{2A^2H}{A^2 - a^2}$ will be very nearly equal to 2H; and by Consequence, the Force generating the whole Motion of the effluent Water, will be very nearly equal to the Weight of a Cylinder of Water, whose Base is $\frac{12}{17}$a, and whose Height is 2H; that is, very nearly equal to the Weight of the Cylinder $\frac{24}{17}$aH: But the Weight of this Cylinder is proportional to the

Weight

Weight of the Cylinder aH, because $\frac{24}{17}$ is an invariable Quantity: And therefore, when the Area of the Hole is extremely ſmall in compariſon of the Area of the Top of the Water, the Force generating the whole Motion of the effluent Water, will be very nearly proportional to the Weight of the Cylinder aH.

The Force generating the Motion of Water flowing thro' a Cylindrical Pipe ſcrew'd into the Side of a Veſſel fill'd with Water, and laid parallel to the Horizon, is ſomething greater than the Force generating the Motion of Water flowing through a Hole whoſe Diameter is equal to that of the Pipe, and which is placed at an equal Diſtance from the Top of the Water; as will appear by conſidering the Nature of theſe two Motions.

In observing the Motion of Water flowing through a Hole made in the Side of a Vessel, we may perceive the Vein not to fill the Hole. Sir *Isaac Newton*, in determining this Motion from Experiments, found the Vein, after it had passed out of the Hole, to grow smaller and smaller, till it came to a Distance very nearly equal to the Diameter of the Hole; at which place he measured the Diameter of the Vein, and found it to be to the Diameter of the Hole, as 21 to 25. The Area of a transverse Section of the Vein at that Distance from the Hole, is to the Area of the Hole; as the Square of the Diameter of the Vein, to the Square of the Diameter of the Hole; that is, as 12 is to 17 nearly. This Contraction of the Vein arises from the Nature of the Motion of the Water down the Vessel: For the Water falls down

down from the Top of the Veſſel to the Hole not perpendicularly but obliquely, its Parts moving laterally as well as downwards. From the Obliquity of this Motion it is, that the Column of the deſcending Water grows narrower perpetually from the Top of the Water to the Hole, and to a ſmall Diſtance beyond it; and that the Vein does not fill the Hole, but falls within it, leaving a little empty Space all round. On account of this Contraction of the Vein, leſs Water flows out, and by Conſequence leſs Motion is generated in a given Time, than would be produced, if the Diameter of the Vein at the Hole was exactly equal to the Diameter of the Hole. And as leſs Motion is generated, ſo the moving Force is likewiſe leſs; being only equal to the Weight of a Cylinder of Water, whoſe Magnitude is $\frac{24}{17}$ a H, when the Hole is extreme-

ly

ly small in comparison of the upper Surface of the Water; whereas it would be equal to the Weight of a Cylinder of Water whose Magnitude is 2 aH, if the Vein filled the Hole and had no Contraction beyond it. And therefore the moving Force is less than it would be if the Vein filled the Hole and had no Contraction beyond it, in the Proportion of 12 to 17.

If instead of flowing through the Hole into the open Air, the Water flows through the Hole into a Cylindrical Pipe, and through that into the Air; and if the Diameter of the Hole be equal to that of the Pipe; the Force generating the Motion of the Water flowing through the Pipe, will be different from the Force generating the Motion of the Water flowing through the Hole.

First,

First, let us ſuppoſe the Pipe to lie parallel to the Horizon; and then the Force generating the Motion of the Water flowing thro' it, will be greater than the Force generating the Motion of the Water flowing thro' the Hole. For the Weight of Water in the Pipe, and the Reſiſtance ariſing from the internal Surface of the Pipe, do both of them, by acting in a kind of Oppoſition to the Weight of the deſcending Cataract in the Veſſel, retard the Motion of the Cataract, and hinder it from flowing ſo faſt into the Pipe, as it does thro' the Hole into the open Air. And by this Oppoſition, they make the Baſe of the Cataract at its Entrance into the Pipe, to ſpread and grow broader; and by Conſequence, encreaſe the moving Force, and make it greater than the Force generating the Motion of the Water flowing

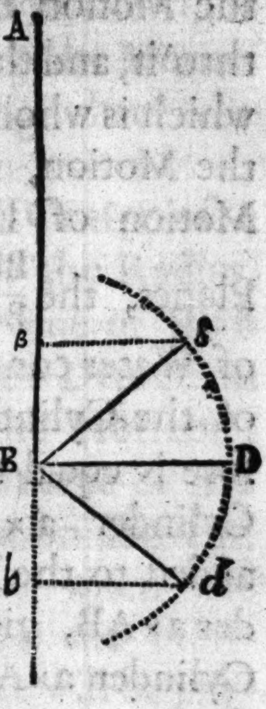
thro' the Hole. Hence it is evident, that the moving Force will encreaſe, either on encreaſing the Length of the Pipe or leſſening its Diameter; and will be greateſt, when the Pipe is infinitely long or infinitely narrow: In which Caſes, the Baſe of the Cataract at its Entrance into the Pipe, will exactly fill it; and the moving Force will be equal to the Weight of a Cylinder of Water, whoſe Magnitude is 2 $\grave{a}$ H; and by Conſequence will be greater than the Force generating the Motion of the Water flowing thro' the Hole, in the Proportion of 17 to 12; and the Motion generated in the Water flowing thro' the Pipe, will be greater than the Motion generated in the Water flowing thro' the Hole; and the Difference of theſe two Motions will be greater when the Pipe is long or narrow, than when it is ſhort or wide. And there-

therefore, if we ſuppoſe the Forces generating the Motions of Water flowing thro' Cylindrical Pipes laid parallel to the Horizon, to be equal to the Forces generating the Motions of Water flowing thro' Holes of equal Diameters, and placed at equal perpendicular Diſtances from the upper Surface of the Water in the Veſſel; on which Suppoſition the Force generating the Motion of Water flowing thro' a Pipe, will be proportional to the Weight of a Cylinder of Water whoſe Magnitude is aH, the Motion of the Water flowing thro' a longer or a narrower Pipe, when compared with the Motion of the Water flowing thro' a ſhorter or a wider Pipe, will be found by Experiments, to be ſomething greater than it ought to be on this Suppoſition of the moving Force. But the Difference will be but ſmall in Pipes of ſmall

Lengths and Diameters; and therefore in the following Experiments, when a Pipe lies horizontally, I ſhall ſuppoſe the moving Force to be proportional to the Weight of the Cylinder aH.

The moving Force will become different, when the Pipe is inclined to the Horizon. The Weight of Water in the Pipe, as far as it encreaſes or leſſens the Motion generated by the Force, which is proportional to the Weight of the Cylinder aH, muſt be added to or ſubducted from that Weight; and the Sum or Difference, will be proportional to the Force generating the Motion of the Water flowing thro' the Pipe in that inclined Poſition. That part of the Weight of the Water in the Pipe, which is to be added to or ſubducted from the Weight of the Cylinder aH, may be thus determined. Let BD repreſent

preſent a Cylindrical Pipe, lying parallel to the Horizon, with its End B inſerted into the Side of a Veſſel at the perpendicular Diſtance of BA from the Top of the Water; the Force generating the Motion of the Water flowing thro' this Pipe, is proportional to the Weight of the Cylinder $a \times AB$; becauſe in this Caſe H is equal to AB. Let the Pipe be turned from its horizontal Poſition, either downwards into the Poſition Bd, or upwards into the Poſition Bδ; and then the moving Force will be changed, and be proportional to the Weight of the Cylinder $a \times Ab$ in the firſt Caſe, and to the Weight of the Cylinder $a \times A\beta$ in the



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the ſecond. For the Weight of the Water in the Pipe Bd, on account of its inclined Situation, encreaſeth the Motion of the Water flowing thro' it, and that part of this Weight, which is wholly ſpent in encreaſing the Motion, is, from the Laws of Motion of Bodies down inclined Planes, the $\frac{Bb}{Bd}$ part of the Weight of Water contained in the Pipe, or of the Cylinder $a \times Bd$; and therefore is equal to the Weight of the Cylinder $a \times Bb$. This Weight added to the Weight of the Cylinder $a \times AB$, gives the Weight of the Cylinder $a \times Ab$; which Weight is the Force generating the Motion of the Water flowing thro' the Pipe Bd. The Weight of Water in the Pipe B*s* leſſens the Motion of the Water flowing thro' it, and that part of the Weight which is wholly ſpent in leſſening the Motion, is the Weight of

of the Cylinder $a \times B\beta$. This Weight ſubducted from the Weight of the Cylinder $a \times AB$, leaves the Weight of the Cylinder $a \times A\beta$, which Weight is the Force generating the Motion of the Water flowing thro' the Pipe $B\delta$.

If B be made the Center of a Circle, and Bd or $B\delta$ the Radius, Bb will be the right Sine of Bdb the Angle of the Pipe's Depreſſion below the Plane of the Horizon; and $B\beta$ will be the right Sine of $B\delta\beta$ the Angle of its Elevation above it. And by Conſequence, when the Pipe is depreſſed below the Horizon, the moving Force will be proportional to the Weight of a Cylinder of Water, whoſe Baſe is equal to the Orifice of the Pipe, and whoſe Altitude is equal to the Sum of the perpendicular Height of the Water in the Veſſel above the place where the Pipe is inſerted, and the right

Sine

Sine of the Angle of Depreſſion of the Pipe below the Plane of the Horizon: And when the Pipe is elevated above the Horizon, the moving Force will be proportional to the Weight of a Cylinder of Water, whoſe Baſe is equal to the Orifice of the Pipe, and whoſe Height is equal to the Difference of the perpendicular Height of the Water in the Veſſel above the place of Inſertion, and the right Sine of the Angle of Elevation of the Pipe above the Plane of the Horizon. If S denotes the right Sine of the Angle, in which the Pipe is depreſſed below or elevated above the Plane of the Horizon; the moving Force will be proportional to the Weight of the Cylinder $a \times \overline{H+S}$, when the Pipe is depreſſed below the Horizon, and proportional to the Weight of the Cylinder $a \times \overline{H-S}$, when it is elevated above it; and comprehending both

both Caſes in one Expreſſion, the moving Force will be as $a \times \overline{H \pm S}$, or as $D^2 \times \overline{H \pm S}$, very nearly.

So then the Velocity of Water flowing thro' a Cylindrical Pipe ſcrew'd into the Side of a Veſſel filled with Water, will be meaſured by $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$. For by this *Propoſition* V is as $\sqrt{\frac{F}{DL}}$: But F is as $D^2 \times \overline{H \pm S}$: And therefore V is as $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$. Another Meaſure of it may be had from Experiments. For the Velocity of Water flowing thro' a Cylindrical Pipe, lying either parallel or inclined to the Horizon, is proportional to the Quantity of Water diſcharged in a given Time, apply'd to the Orifice of the Pipe. For the Quantity diſcharged in a given Time, apply'd to the Orifice of the Pipe, will give the Length of a Cy-

lindrical Pipe which can just contain that Quantity; which Length is the Space that would be described in the Time of the Motion by an uniform Velocity, equal to the Velocity with which the Fluid flows thro' the Pipe when the moving Force acts constantly and uniformly, as it will do if the Vessel be kept constantly full, by pouring in Water very gently at the Top as fast as it runs out of the Pipe. But the Velocities of all uniform Motions are as the Spaces described in a given Time; and by Consequence, the uniform Velocity with which the Length of the said Cylinder would be described in the given Time of the Motion, will be proportional to that Length; and therefore proportional to the Quantity of Fluid discharged apply'd to the Orifice of the Pipe. Let M denote the Quantity of Water discharged in the

the given Time of the Motion; and then the Velocity V will be proportional to, and consequently measured by, $\frac{M}{a}$ or $\frac{M}{D^2}$ because Circles are to one another as the Squares of their Diameters.

If the Velocity be rightly measured by this *Proposition*, then $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$ must be proportional to $\frac{M}{D^2}$ very nearly; as it will appear to be by the following Experiments, setting aside the Resistance of the Air.

Tho' in this *Proposition* I have set aside the Resistance given by the Air to this Motion, yet it will be necessary to consider it, in order rightly to understand the Disturbances in the Motion caused by it. Water in flowing out of a Pipe into the open Air, communicates a Motion to the Air, and loses so much

of its own Motion as it communicates. Now if we ſuppoſe the Motion communicated to be proportional to the Square of the Diameter of the Vein of the effluent Water, and the Square of its Velocity, taken together; then the Motion communicated to the Air, with reſpect to the Motion which in the ſame Time would be generated in the Water, ſetting aſide the Reſiſtance of the Air, and that which ariſes from the internal Surface of the Pipe, will be reciprocally as the Length of the Pipe. And by Conſequence, in Pipes of the ſame Length, the Motions communicated to the Air, will on this Suppoſitien be proportional to thoſe which would be generated in the Water if there was no Air, nor any Reſiſtance ariſing from the internal Surfaces of the Pipes. And therefore the Reſiſtance of the Air will

cauſe

caufe no Difturbance in the Proportions of the Motions of the Water flowing thro' fuch Pipes. This Suppofition, that the Veins of the effluent Water are refifted by the Air, in Proportion to the Squares of their Diameters and the Squares of their Velocities, taken together, will not appear unreafonable, when we confider that folid Globes in moving thro' the Air, are refifted in that Proportion.

Experiment 1. Three Cylindrical Pipes, whofe Lengths were two, four, and eight Feet, and whofe common Diameter was $\frac{345}{1000}$ parts of an Inch, were one after another fcrewed into the Side of the Veffel at the perpendicular Diftance of four Feet from the Top of the Water, and laid parallel to the Horizon. Thefe three Pipes thus fituated, difcharged 175, 133, and $97\frac{1}{2}$ *Troy* Ounces of Water in half

a Minute. The Pipes having equal Diameters, the Velocities of the Water flowing thro' them were as the Quantities of Water discharged in equal Times; that is, as the Numbers 175, 133, and $97\frac{1}{2}$: For when D is given, V is as M. By the other Measure of the Velocity deduced from this *Proposition*, the Velocities ought to have been reciprocally as the Square Roots of the Lengths of the Pipes; that is, nearly as the Numbers 20000, 14142, and 10000. For the Pipes having equal Diameters, being all inserted into the Side of the Vessel at the same perpendicular Distance from the Top of the Water, and all laid parallel to the Horizon; D and H were given, and S was 0; and consequently the Velocity, which I have shewn to be measured by $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$, ought in the present Case

to

to have been as $\frac{1}{\sqrt{L}}$. The Velocities from this Meaſure are nearly proportional to thoſe from Experiments. Thoſe from Experiments with reſpect to theſe, are as the Numbers 175, 188, 195: whence it appears, that the Velocity from Experiment, with reſpect to the Velocity expreſſed by the other Meaſure, is ſomething greater in the longer of any two of theſe Pipes than in the ſhorter; as it ought to be, from what has been ſaid, both on account of the Reſiſtance of the Air, and the Nature of the moving Force.

Experiment 2. Three Cylindrical Pipes, whoſe Lengths were equal, and whoſe Diameters were $\frac{372}{1000}$, $\frac{185}{1000}$, and $\frac{90}{1000}$ parts of an Inch, being one after another ſcrew'd into the Side of the Veſſel, at the perpendicular Diſtance of four Feet from the Top of

of the Water, and laid parallel to the Horizon, discharged 179, $33\frac{1}{2}$, and $6\frac{1}{8}$ Ounces of Water in half a Minute. The Velocities, found by dividing these Quantities by the Squares of the Diameters of their respective Pipes, were as the Numbers 1293, 979, and 756. By the other Measure they ought to have been as the Square Roots of the Diameters of the Pipes; that is, nearly as the Numbers 193, 136, and 94. For the Pipes having equal Lengths, being all inserted into the Side of the Vessel at the same perpendicular Distance from the Top of the Water, and being laid parallel to the Horizon; L and H were given, and S was o; consequently $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$ was in this Case as $\sqrt{D}$. The Velocities from this Measure are nearly proportional to those from Experiments. Those from

from Experiments, with reſpect to theſe, are as the Numbers 670, 720, 804; whence it appears, that the Velocity from Experiment, with reſpect to what it ought to be by the Meaſure of this *Propoſition*, is ſomething greater in the narrower of any two of theſe Pipes than in the wider; as I have ſhewn it ought to be, from the Nature of the moving Force.

Experiment 3. Two Cylindrical Pipes, whoſe Lengths were eight Feet and two Feet, and whoſe Diameters were $\frac{245}{1000}$ and $\frac{185}{1000}$ parts of an Inch, were ſcrew'd into the Side of the Veſſel at the perpendicular Diſtances of four Feet, and one Foot from the Top of the Water, and were laid parallel to the Horizon. Theſe Pipes thus fixed diſcharged $87\frac{1}{2}$, and 16 Ounces of Water in half a Minute. The Velocities in them, found by dividing their Diſcharges

by the Squares of their Diameters, were nearly as the Numbers 73, and 46. By the other Meaſure of the Velocity they ought to have been as the Square Roots of the Diameters of the Pipes; that is, nearly as the Numbers 186 and 136: For H and L were each of them four in the firſt Experiment, and one in the ſecond, and S was nothing in both; and conſequently the Velocity, expreſſed by $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$, in the preſent Caſe was as $\sqrt{D}$. The Velocity in the Pipe which was nearer to the Top of the Veſſel, was leſs than it ought to have been by this Meaſure, in the Proportion of 34 to 39. And in all the Experiments I have made upon this Occaſion, I have always found the Velocities in the ſame Pipes placed at different Diſtances from the Top of the Water, to be leſs at leſs Diſtances from the Surface

Surface than at greater, with respect to what they ought to have been by this *Proposition*. This Defect of Velocity may be owing, partly to a Disturbance given to the Motion by the Water, which was poured in at the Top of the Vessel in order to keep it constantly full, which Disturbance, being greater at a less Distance from the Surface, might cause a greater Loss of Motion; and partly to the moving Force's being in reality something greater at a greater Distance from the Top of the Water, than it ought to be by the Measure I have given of it.

Experiment 4. Two Cylindrical Pipes of equal Diameters, and of the Lengths 1 and 4, were one after the other screw'd into the Side of the Vessel at the perpendicular Distance of four Feet from the Top of the Water, and were each of

them depressed in an Angle of 30 Degrees below the Plane of the Horizon. These Pipes thus situated discharged $41\frac{3}{8}$ and $25\frac{5}{8}$ Ounces of Water in half a Minute. The Velocities in these Pipes, on account of their having equal Diameters, were as the Quantities discharged. By the other Measure they ought to have been as the Numbers 300 and 173. For the Pipes having equal Diameters, and being both depressed below the Horizon, that Measure became $\sqrt{\frac{H+S}{L}}$. The natural Sine of 30 Degrees being equal to half the Radius, S was half a Foot for the shorter Pipe, and two Feet for the longer; and $\frac{H+S}{L}$ was $4\frac{1}{2}$ for the first, and $\frac{5}{4}$ or $\frac{3}{2}$ for the second; or 9 for the first, and 3 for the second. But the Square Roots of 9 and 3 are as the Numbers 300 and 173, which Numbers are nearly

ly in the ſame Proportion as the Numbers $41\frac{3}{8}$, and $25\frac{5}{8}$; and therefore the Velocities were nearly in the ſame Proportion, as they ought to have been by this *Propoſition*.

PROPOSITION II.

IF a given Fluid flows through two Syſtems of Cylindrical Pipes made of a given Sort of Matter, and conſiſting each of one Trunk, and the ſame Number of Branches ariſing from it; if the Pipes of the two Syſtems have like Situations and Capacities, that is, if any two correſponding Pipes be ſimilarly ſituated with reſpect to the reſt of the Pipes, and their Capacities be as the Capacities of the whole Syſtems; And if the Forces generating the Motions in two correſponding Pipes be in the ſame

same Proportion as the whole moving Forces of the two Systems: The Velocities in the two corresponding Pipes, setting aside the Resistance of the Air, will be in Ratios compounded of the subduplicate Ratios of the whole moving Forces of the two Systems directly, and of the subduplicate Ratios of the Diameters and Lengths of the Pipes taken together inversly. If V, v *be put for the Velocities in the two Pipes;* D, d, *and* L, l *for their Diameters and Lengths; and* F, f *for the whole moving Forces of the two Systems; I say, that* $V . v :: \sqrt{\frac{F}{DL}} . \sqrt{\frac{f}{dl}}$.

For by the *First Proposition*, the Velocities in any two corresponding Pipes of the two Systems, setting aside the Resistance of the Air, are to each other in Ratios compounded of the subduplicate Ratios of the

the Forces generating the Motions in the two Pipes directly, and of the ſubduplicate Ratios of the Diameters and Lengths of the Pipes taken together inverſly: But by Suppoſition the Forces generating the Motions in the two Pipes are in the ſame Proportion as the whole moving Forces of the two Syſtems: And therefore by Proportion of Equality, the Velocities in the two correſponding Pipes, ſetting aſide the Reſiſtance of the Air, will be in Ratios compounded of the ſubduplicate Ratios of the whole moving Forces of the two Syſtems directly, and of the ſubduplicate Ratios of the Diameters and Lengths of the two Pipes inverſly.

Proof

Proof by EXPERIMENTS.

Experiment I.

I Had two Syſtems of Cylindrical Pipes made of Braſs, each of which conſiſted of a Trunk and two Branches. The larger Branch of each Syſtem was a Continuation of its Trunk, having an equal Diameter, and lying in a right Line with it; and the ſmaller Branch of each made an Angle of 30 Degrees with the larger. The Trunks and Branches of the two Syſtems were each of them one Foot in Length; the Diameter of the Trunk and larger Branch in the greater Syſtem was $\frac{345}{1000}$, and the Diameter of the ſmaller Branch $\frac{187}{1000}$ parts of an Inch; and the Diameter of the Trunk and larger

larger Branch in the leſſer Syſtem was $\frac{182}{1000}$, and the Diameter of the ſmaller Branch $\frac{90}{1000}$ parts of an Inch. The Trunks of theſe two Syſtems were ſucceſſively ſcrew'd into the Side of the Veſſel at the perpendicular Diſtance of four Feet from the Top of the Water, and were turned till their Branches lay parallel to the Horizon. In this Situation, the Branches of the greater Syſtem diſcharged $169\frac{1}{2}$ and 20, and the Branches of the leſſer $30\frac{1}{4}$ and 4 Ounces of Water in half a Minute. The Velocities in the Trunks and Branches of theſe Syſtems, found by dividing the Quantities which flow'd thro' them in a given Time by the Squares of their reſpective Diameters, were as the Numbers 1592, 1424, and 572 in the Trunk and Branches of the greater Syſtem; and as the Numbers 979, 865, and 494 in the Trunk and Branches of

the lesser. The Quantities of Water contained in these two Systems, were as the Numbers 273 and 78; as I found by multiplying the Squares of the Diameters of the several Pipes into their Lengths, and then adding the Products of each System into one Sum. Since all the Pipes of the two Systems were at the same perpendicular Distance from the Top of the Water, and lay parallel to the Horizon, in which Position the Weights of Fluid contained in the Pipes made no part of the Forces generating the Motions of the Water flowing thro' them, the Forces generating the Motions in the Trunks and corresponding Branches, were as the Squares of their Diameters, or as the Quantities of Water contained in them, because they all had the same Length. And therefore had these two Systems been truly made, so as

to

to have had the Conditions required in the *Propoſition*, that is, had the Quantities of Water contained in the Trunks and correſponding Branches been exactly proportional to the whole Quantities of Water contained in the two Syſtems; the Velocities in thoſe Pipes, ſetting aſide the Reſiſtance of the Air, ought to have been in the ſubduplicate Ratios of their Diameters directly. But the Capacity of the leſſer Branch of the greater Syſtem compared with the Capacity of that Syſtem, was greater than the Capacity of the leſſer Branch of the leſſer Syſtem compared with the Capacity of its Syſtem, in the Proportion of 5 to 4 nearly. The Velocity by Experiment in the leſſer Branch of the greater Syſtem compared with the Velocity by the Theory, was leſs than it would have been had the Branch

been truly conſtructed; which agrees with what I have already ſhewn both from Experiments and Reaſon, namely, that in Pipes of different Diameters but equal Lengths the Velocity by Experiment compared with the Velocity by the Theory, is always greateſt in the narroweſt Pipes. The Velocity by Experiment with reſpect to the Velocity meaſured by the Square Root of the Diameter of the Pipe, was leſs in the ſmaller Branch of the greater Syſtem than in the ſmaller Branch of the leſſer Syſtem, in the Proportion of 21 to 26. As the Capacity of the ſmaller Branch with reſpect to the Capacity of the Syſtem, was ſomething greater in the greater Syſtem than in the leſſer; ſo the Capacity of the Trunk or larger Branch with reſpect to the Capacity of the Syſtem, was on the contrary ſomething leſs in the

greater

greater Syſtem than in the leſſer; and by Conſequence, from what has been ſaid concerning the Nature of the moving Force, the Velocity by Experiment with reſpect to the Velocity meaſured by the Square Root of the Diameter of the Pipe, was greater in the Trunk and larger Branch of the greater Syſtem, than it was in the Trunk and larger Branch of the leſſer: In the Trunk it was greater in the Proportion of 43 to 36, and in the Branch it was greater in the Proportion of *76* to 63. Theſe Deviations of the Theory from Experiments, are not Objections againſt it, but rather Arguments of its Truth; ſince they all ariſe, and may be accounted for, from the Syſtems not having exactly the Conditions required in this *Propoſition*.

Experiment II. Two Syſtems of Cylindrical Pipes, the leſſer of which was

was the greater of the two Syſtems uſed in the laſt Experiment, and the greater a Syſtem four times as large, its Trunk and Branches having the ſame Diameters, and being four times as long as the Trunk and Branches of the leſſer, had their Trunks ſucceſſively ſcrew'd into the Side of the Veſſel at the perpendicular Diſtance of four Feet from the Top of the Water, and had both their Trunks and Branches laid parallel to the Horizon: In this Poſition the Branches of the greater Syſtem diſcharged $90\frac{3}{4}$, and $13\frac{1}{2}$; and the Branches of the leſſer $169\frac{1}{2}$, and 20 Ounces of Water in half a Minute. The Diameters of the Trunks and correſponding Branches of the two Syſtems being equal; the Velocities in thoſe Pipes were as the Weights or Quantities of Water which flow'd thro' them in a given Time, that is, as the Numbers

$104\frac{1}{4}$,

$104\frac{1}{4}$, $90\frac{3}{4}$, $13\frac{1}{2}$ in the Trunk and Branches of the greater Syſtem; and as the Numbers $189\frac{1}{2}$, $169\frac{1}{2}$, 20 in the Trunk and Branches of the leſſer. The Diameters of the correſponding Pipes of the two Syſtems being equal, and the Pipes lying parallel to the Horizon, and at the ſame perpendicular Diſtance from the Top of the Water; D and H were given, and S was o; and conſequently the other Meaſure of the Velocity $\sqrt{\frac{D \times \overline{H \pm S}}{L}}$ in this became $\frac{1}{\sqrt{L}}$. Whence the Velocities in the correſponding Pipes of the Syſtems ought to have been in the inverſe ſubduplicate Ratios of the Lengths of thoſe Pipes, that is, they ought to have been twice as great in the Trunk and Branches of the ſhorter Syſtem as in the Trunk and correſponding Branches of the longer,

as they nearly were; only they were ſomething greater in the longer Syſtem than they ought to have been, partly from a leſs Reſiſtance of the Air, and partly from the Nature of the moving Force, which from what has been ſaid concerning its Meaſure, was ſomething greater in the longer Syſtem than in the ſhorter.

Experiment III. I placed the two Syſtems, uſed in the laſt Experiment, at different perpendicular Diſtances from the Top of the Water, with their Trunks and Branches parallel to the Horizon; and always found the Velocities in the Trunk and Branches of each Syſtem, to be nearly in the ſubduplicate Ratios of the perpendicular Diſtances of the Syſtem from the Top of the Water; only at leſs Diſtances they were ſomething leſs than they ought to have been by this Meaſure, for the

Reaſons aſſigned in the third Experiment of the firſt *Propoſition.*

Experiment IV. The two Syſtems uſed in the ſecond and third Experiments, were one after the other ſcrew'd into the Side of the Veſſel at different perpendicular Diſtances from the Top of the Water, the leſſer at the Diſtance of one Foot, and the greater at the Diſtance of four Feet; and were turned till the leſſer Branch of each Syſtem was depreſſed in an Angle of 30 Degrees below the Plane of the Horizon, while the Trunk and larger Branch of each Syſtem lay parallel to it: In theſe Situations, the Branches of the greater Syſtem diſcharged $89\frac{1}{2}$, $17\frac{1}{8}$; and the Branches of the leſſer 79, $13\frac{3}{4}$ Ounces of Water in half a Minute. The Diameters of the correſponding Pipes being equal; the Velocities in them were as the Quantities of Water which flowed

thro' them in the given Time of the Motion, that is, as $106\frac{5}{8}$, $89\frac{1}{2}$, $17\frac{1}{8}$ in the Trunk and Branches of the greater System; and as $92\frac{1}{4}$, 79, $13\frac{1}{4}$ in the Trunk and Branches of the lesser. The Diameters of the corresponding Pipes being equal, and the perpendicular Distances of the Systems from the Top of the Water being as the Lengths of the Systems, and the Systems being situated alike with respect to the Horizon; D and S were given, and H was proportional to L; consequently in this Case the other Measure of the Velocity became a given Quantity; whence the Velocities in the corresponding Branches ought by that Measure to have been equal. Their Differences were not great, and probably arose chiefly from the lesser System being placed nearer to the Top of the Water than the greater.

PRO-

Proposition III.

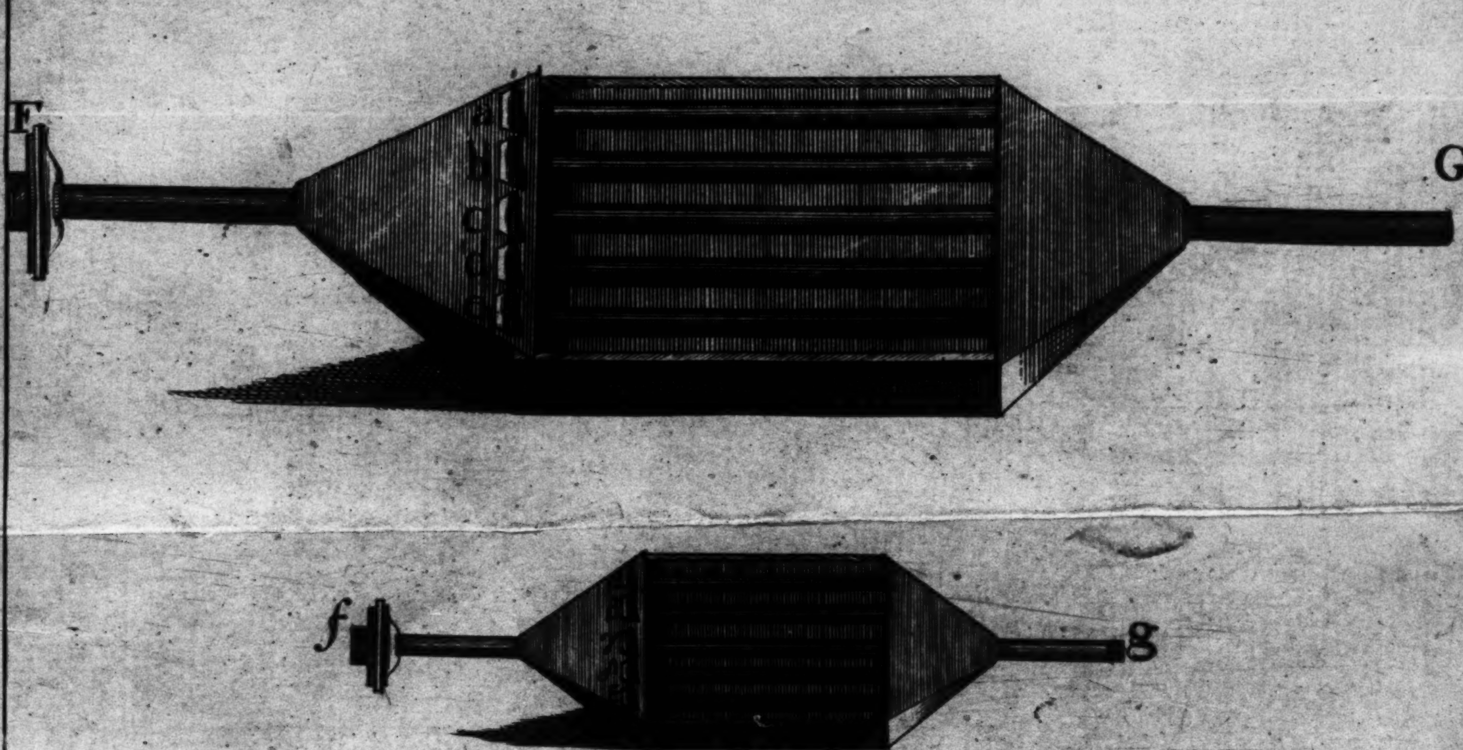
IF a given Fluid flows thro' two Systems of Cylindrical Pipes made of a given Sort of Matter, and consisting each of two Trunks, and the same Number of Branches similar in their Situations and Capacities, that is, if any two corresponding Pipes be similarly situated with respect to the rest of the Pipes, and their Capacities be as the Capacities of their whole Systems, if in each System the last and smallest Branches of the two Trunks be continuous, and if the Forces generating the Motions in any two corresponding Pipes be in the same Proportion as the whole moving Forces of the two Systems; The Velocities in those Pipes, setting aside the Resistance of the Air, will be in Ratios com-

compounded of the subduplicate Ratios of the whole moving Forces of the two Systems directly, and of the subduplicate Ratios of the Diameters and Lengths of the Pipes taken together inversly, that is, $V.v::\surd\frac{F}{DL}.\surd\frac{f}{dl}$

For by the *First Proposition*, the Velocities in any two corresponding Pipes of the two Systems, setting aside the Resistance of the Air, are in Ratios compounded of the subduplicate Ratios of the Forces generating the Motions in those Pipes directly, and of the subduplicate Ratios of their Diameters and Lengths taken together inversly: But by Supposition, the Forces generating the Motions in two corresponding Pipes, are as the whole moving Forces of the two Systems: And therefore by Proportion of Equality, the Velocities in two

cor-

P. 53



corresponding Pipes, setting aside the Resistance of the Air, will be in Ratios compounded of the subduplicate Ratios of the whole moving Forces of the two Systems directly, and of the subduplicate Ratios of the Diameters and Lengths of those Pipes taken together inversly.

Proof by EXPERIMENTS.

TO confirm the Truth of this *Proposition* by Experiments, I got made of Brass two such Systems of Cylindrical Pipes as are represented in these Figures. Each System consisted of two Trunks and five Branches all lying in one and the same Plane. The Trunks and Branches of each had equal Diameters

meters and Lengths. The common Diameter of the Trunks and Branches of the greater Syſtem, was $\frac{187}{1000}$; and the common Diameter of the Trunks and Branches of the leſſer Syſtem, was $\frac{90}{1000}$ parts of an Inch. The common Length of the Trunks and Branches of the greater Syſtem, was half a Foot; and the common Length of the Trunks and Branches of the leſſer, three Inches. The Trunks of each Syſtem opened into the Branches, thro' two pyramidal Spaces, which were each three Inches long in the greater Syſtem, and an Inch and a half in the leſſer; and their Capacities were nearly in the ſame Proportion as the Capacities of their Trunks or Branches, that is, in the Proportion of 87 to 10. When the Ends F and f were ſcrew'd into the Side of the Veſſel at the perpendicular Diſtance of four Feet from the Top of the

the Water, and the Syſtems were turned till their Branches lay parallel to the Horizon; their other Ends G and g diſcharged $36\frac{5}{8}$ and $6\frac{1}{8}$ Ounces of Water in half a Minute. The Velocities in the Trunks, found by dividing the Diſcharges by the Squares of their Diameters, were as the Numbers 1047 and 1003 nearly. And by this *Propoſition* they ought to have been as the Numbers 883 and 866, which are proportional to the Numbers 1047 and 1003 very nearly. And ſince the Syſtems were ſimilar, and ſimilarly ſituated, no Doubt can be made, but that the Velocities in correſponding Branches were likewiſe in the ſame Proportion.

PRO-

Proposition IV.

IF a given Fluid flows thro' two compounded Systems of Cylindrical Pipes, consisting each of two Cylindrical Trunks, and the same Number of smaller Systems like those described in the last Proposition, *the Trunks of which smaller Systems open into their respective principal Trunks of the compounded Systems, if all the corresponding Pipes of the compounded Systems have like Situations and Capacities, that is, if any two corresponding Pipes be similarly situated with respect to the rest of the Pipes, and their Capacities be in the same Proportion as the whole Capacities of the compounded Systems; and if the Forces generating the Motions in any two corresponding Pipes be as the*

the whole moving Forces of the two compounded Syſtems; the Velocities in thoſe Pipes, ſetting aſide the Reſiſtance of the Air, will be in Ratios compounded of the ſubduplicate Ratios of the whole moving Forces of the two compounded Syſtems directly, and of the ſubduplicate Ratios of the Diameters and Lengths of the Pipes taken together inverſly, that is, V . v : : $\sqrt{\frac{F}{DL}} . \sqrt{\frac{f}{d\,l}}$

The Demonſtration of this *Propoſition* is the ſame with that of the laſt, and therefore need not be repeated.

Cor. 1. If the whole moving Forces of the two compounded Syſtems be as the Capacities of thoſe Syſtems, that is, as the Capacities of any two correſponding Pipes; the Velocities in thoſe Pipes, ſetting

H aſide

aside the Resistance of the Air, will be in the subduplicate Ratios of their Diameters. If $F . f :: D^2 L . d^2 l$; then will $V . v :: \sqrt{D} . \sqrt{d}$.

Cor. 2. If the whole moving Forces of the two compounded Systems be as the Capacities of the Systems, that is, as the Capacities of any two corresponding Pipes, and the Diameters of corresponding Pipes be in the subduplicate Ratios of their Lengths, or of the Lengths of the Systems; the Velocities in corresponding Pipes, setting aside the Resistance of the Air, will be in the subquadruplicate Ratios of the Lengths of the Systems. If $F . f :: D^2 L . d^2 l$, and $D . d :: \sqrt{L} . \sqrt{l}$; then will $V . v :: L^{\frac{1}{4}} . l^{\frac{1}{4}}$.

Cor. 3. If the whole moving Forces of the two compounded Systems be as the m Power of their Capa-

Capacities, and conſequently as the m Power of the Capacities of any two correſponding Pipes, and the Diameters of thoſe Pipes be as the n Power of their Lengths, or as the n Power of the Lengths of the Syſtems; the Velocities in two ſuch Pipes, ſetting aſide the Reſiſtance of the Air, will be in the $\frac{2nm+m-n-1}{2}$ Power of the Lengths of the Syſtems. If $F . f : : D^2 L^m . d^2 l^m$, and $D . d : : L^n . l^n$; then will $V . v : : L^{\frac{2nm+m-n-1}{2}} . l^{\frac{2nm+m-n-1}{2}}$.

Cor. 4. The whole moving Forces of the two compounded Syſtems are in Ratios compounded of the duplicate Ratios of the Velocities in two correſponding Pipes, and of the ſimple Ratios of their Diameters and Lengths, that is, $F . f : : V^2 DL . v^2 dl$.

Scholium.

This *Proposition* will hold true, if the two Systems be made of Conical Pipes equal in their Capacities and Lengths to the Cylindrical ones, and so obstructed, as that the greatest or least Diameters of any two corresponding Conical Pipes shall every where bear the same Proportion to each other, as the Diameters of the two Cylindrical Pipes which are equal to them.

PROPOSITION V. Problem I.

THE Velocity of a given Fluid moving thro' a Cylindrical Pipe of a given Diameter and Length, and the Force generating the Motion, being given; it is required to determine the Velocities generated by an equal Force

Force in the ſeveral Parts of a Syſtem like one of thoſe deſcribed in the Third Propoſition.

The two Forces generating the Motions in the Cylindrical Pipe and in this Syſtem being equal by Suppoſition; their Meaſures will be ſo too. For the Force generating the whole Motion in the Syſtem, is the Sum of the Forces generating the Motions in all its Parts; and the Meaſures of the Forces generating the Motions in the ſeveral Parts of the Syſtem, are in Ratios compounded of the duplicate Ratios of the Velocities in thoſe Parts, and of the ſimple Ratios of their Lengths and Diameters; by *Cor. 7. Prop.* 1. Wherefore putting L for the Length of the Cylindrical Pipe, D for its Diameter, V for the Velocity of the Fluid moving through it; l for the Length of that Trunk thro'

which

which the Fluid flows into the Syſtem, d for its Diameter, and x for the Velocity of the Fluid flowing thro' it; Λ for the mean Length of the Branches, Δ for the Diameter of a Cylinder whoſe Length is that mean Length, and whoſe Orifice is equal to the Sum of the Orifices of all the Branches; λ for the Length of the other Cylindrical Trunk, and δ for its Diameter: the Meaſure of the Force generating the Motion of the Fluid flowing thro' the Cylindrical Pipe will be $V^2 D L$; and the Meaſure of the Force generating the Motion in that Trunk which leads into the Syſtem will be $x^2 d l$. The mean Velocity in the Branches, is to x the Velocity in that Trunk, as d^2, is to Δ^2; becauſe the Velocities of the ſame Quantity of Fluid flowing thro' two Cylindrical Pipes in the ſame Time, are reciprocally proportional to the Squares of their

Dia-

Diameters; whence the mean Velocity in the Branches will be $\frac{xd^2}{\Delta^2}$; and the Measure of the Force generating the Motion in the Branches taken all together, will be $\frac{x^2 d^4 \Lambda}{\Delta^3}$: By the same Reasoning the Velocity in the other Trunk thro' which the Fluid flows out of the System, will be $\frac{xd^2}{\delta^2}$; and the Measure of the Force generating the Motion of the Water flowing through it, will be $\frac{x^2 d^4 \lambda}{\delta^3}$: But the Sum of the Forces generating the Motions in all the Parts of the System, is by Supposition equal to the Force generating the Motion in the Cylindrical Pipe; and by Consequence, $x^2 dl + \frac{x^2 d^4 \Lambda}{\Delta^3} + \frac{x^2 d^4 \lambda}{\delta^3} = V^2 DL$; whence x is equal to $\frac{V}{d^2}\sqrt{\frac{DL}{\frac{l}{d^3}+\frac{\Lambda}{\Delta^3}+\frac{\lambda}{\delta^3}}}$.

If

If this Value of x be ſubſtituted in its Room in $\frac{xd^2}{\Delta^2}$, the Meaſure of the mean Velocity in the Branches; that Meaſure will become $\frac{V}{\Delta^2}$

$$\sqrt{\frac{DL}{\frac{l}{d^3}+\frac{\Lambda}{\Delta^3}+\frac{\lambda}{\delta^3}}}.$$

If the ſaid Value of x be ſubſtituted in its Room in $\frac{xd^2}{\delta^2}$, the Meaſure of the Velocity in the other Trunk; that Meaſure will become

$$\frac{V}{\delta^2}\sqrt{\frac{DL}{\frac{l}{d^3}+\frac{\Lambda}{\Delta^3}+\frac{\lambda}{\delta^3}}}.$$

Cor. 1. If the Capacity of the Branches be encreaſed by an Enlargement of their Diameters or an Encreaſe of their Number, that is, if Δ be encreaſed, all other Things continuing the ſame; the Velocities generated by a given Force, will be

be greater in the Trunks and leſs in the Branches, than they were before this Change happened in the Capacity of the Branches.

Cor. 2. If the Capacity of the Branches be leſſened by a Contraction of their Diameters or a Decreaſe of their Number, that is, if Δ be diminiſhed, all other Things continuing the ſame; the Velocities generated by a given Force, will be leſs in the Trunks and greater in the Branches, than they were before this Change was made in the Capacity of the Branches.

Cor. 3. If the two Trunks of the Syſtem be given; the Velocities generated by a given Force, will be greateſt in the Trunks and leaſt in the Branches, when Δ is infinite; in which Caſe the Term $\frac{\Lambda}{\Delta^2}$ will va-

nish or become nothing: The Velocity in the Trunk, through which the Fluid flows into the System, will be measured by $\frac{V}{d^2}\sqrt{\frac{DL}{\frac{l}{d^3}+\frac{\lambda}{\delta^3}}}$: The Velocity in the Branches will be infinitely little: And the Velocity in the other Trunk will be $\frac{V}{\delta^2}\sqrt{\frac{DL}{\frac{l}{d^3}+\frac{\lambda}{\delta^3}}}$.

Cor. 4. If the Velocity in the given Cylindrical Pipe be equal to the Velocity in that Trunk thro' which the Fluid flows into the System, that is, if V be equal to x, and consequently V^2 equal to x^2; and if the Diameter of the Pipe, be equal to the Diameter of that Trunk, that is, if D be equal to d; then the Length of the Cylindrical Pipe or L, will be equal to $l+\frac{d^3\Lambda}{\Delta^3}+\frac{d^3\lambda}{\delta^3}$.

Cor.

Cor. 5. If the Branches taken together, be wider than either of the Trunks; the mean Velocity in them will be leſs than it is in the Trunks: And if one Trunk be wider than the other, the Velocity will be leſs in Proportion as the Trunk is wider.

Proof by EXPERIMENTS.

THE greater of the two Syſtems, which were made for the Proof of the *Third Propoſition*, was ſcrewed into the Veſſel at the perpendicular Diſtance of four Feet from the Top of the Water, and turned till its Branches were parallel to the Horizon. The Branches of this Syſtem were ſo contrived, that their Ends which were next to the Veſſel might be opened or ſhut by little

Braſs Valves or Sliders. This Syſtem being thus ſituated, when the Branch C only was open; the Trunk G diſcharged 29½ Ounces of Water in half a Minute: When the three Branches b, c, d were open, it diſcharged 36 Ounces in half a Minute: And when all the five Branches were open, it diſcharged 36⅜ Ounces in the ſame Time. The Velocities in the two equal Trunks, were as the Quantities diſcharged. When one Branch only was open, the Velocity in that Branch, was equal to the Velocity in the Trunk; and therefore the Velocity in the Branch C, when the reſt of the Branches were ſhut, was as 29½. The mean Velocity in the three Branches, found by applying 36 to 3 the Sum of their Orifices, the Orifice of each of the Trunks being 1, was as 12: and the Velocity in the five Branches, when they were all

all open, found by dividing $36\frac{5}{8}$ by 5, was as $7\frac{13}{40}$. These were the true Velocities in the Trunks and Branches in these three Experiments. I shall now shew what they ought to have been by this Problem.

The two Trunks and Branch G taken together, may be considered as one Cylindrical Pipe; and therefore may represent the given Cylindrical Pipe in this Problem, in which the Velocity V is as $29\frac{3}{8}$. The Trunks and Branches of this System having all equal Diameters, D, d, and δ were equal. The Lengths of the two Trunks were equal, and when added together, their Sum was equal to the Length of the Branches added to the Lengths of the two pyramidal Spaces into which they opened; therefore l was equal to λ, and $l + \lambda$ equal to Λ if the pyramidal Spaces be considered as Parts

Parts of the Branches, on which Suppoſition L was equal to $l + \lambda + \Lambda$; and by Conſequence equal to two Feet; and l and λ were each half a Foot, and Λ one Foot. The Velocity in the Trunks, d being 1, will be expreſſed by $29\frac{1}{4} \sqrt{\frac{2}{1+\frac{1}{\Delta^3}}}$; therefore when three Branches were open, and by Conſequence Δ equal to $\sqrt{3}$, the Velocity ought to have been nearly as 38: And nearly as 40, when all five were open, and Δ equal to $\sqrt{5}$.

The Velocities in the Branches, expreſſed by $\frac{29\frac{1}{4}}{\Delta^2} \sqrt{\frac{2}{1+\frac{1}{\Delta^3}}}$, ought to have been $12\frac{2}{3}$, when three Branches were open; and 8, when all five were open. The near Agreement of theſe Velocities with thoſe from Experiments, ſhews the Velocities in the Trunks and Branches of this Syſtem to

to be rightly determined by this Problem.

PROPOSITION VI.

IF a given Fluid flows thro' a simple System of Cylindrical Pipes, consisting of one Trunk and any Number of Branches; the Velocity in any Pipe will be greater or less, according as the moving Force of the System is greater or less, as the Pipe is wider or narrower, shorter or longer, nearer to or farther from the moving Force, as the Weight of Fluid in the Pipe conspires with or opposes its Motion, or as any of the other Pipes of the System is lengthened or shortened.

That the Velocity in any Pipe of this System is greater or less, as the moving Force of the System is greater

greater or leſs, as the Pipe is wider or narrower, ſhorter or longer, or as the Weight of Fluid contained in the Pipe conſpires with or oppoſes its Motion; has been fully proved in the foregoing *Propoſitions*. And that the Velocity is greater or leſs, as the Pipe is nearer to or farther from the moving Force, may be thus proved. From the Nature of this Motion, the whole moving Force is reſiſted by the Quantity of Fluid contained in the whole Syſtem: And that part of this Force which moves the Fluid through any Pipe, is reſiſted by the Quantity of Fluid in that part of the Syſtem which lies before it; the Reſiſtance therefore will be greater or leſs, as a Pipe is nearer to or farther from the moving Force: But as the Reſiſtance is greater or leſs, the Preſſure of the moving Fluid againſt the Orifice of the Pipe, and conſequently the

the Velocity in the Pipe, is greater or leſs; and therefore, *cæteris paribus*, the Velocity in a Pipe is greater or leſs, as it is nearer to or farther from the moving Force. Laſtly, the Velocity in a Pipe will be greater or leſs, *cæteris paribus*, as any of the other Pipes of the Syſtem is lengthened or ſhortened: For by lengthening or ſhortening a Pipe, the Reſiſtance given by the Fluid contained in it to that part of the moving Force of the Syſtem which is ſpent on that Pipe, becomes greater or leſs than it was before: But a greater or leſs Reſiſtance makes the moving Force to act more or leſs powerfully on the other Pipes, and encreaſes or leſſens the Velocities in them: And therefore the Velocity in a Pipe will be encreaſed or leſſened, *cæteris paribus*, as any of the other Pipes is lengthened or ſhortened.

Proof by EXPERIMENTS.

THAT the Velocity in a Pipe of this Syſtem is greater or leſs, as the moving Force of the Syſtem is greater or leſs, as the Weight of Fluid contained in it conſpires with or oppoſes its Motion, or as the Pipe is wider or narrower, ſhorter or longer, is fully proved by the Experiments of the foregoing *Propoſitions*. And that the Velocity is greater or leſs, as the Pipe is nearer to or farther from the moving Force, or as any other Pipe of the Syſtem is lengthened or ſhortened, will appear from the following Experiments.

A Syſtem of Cylindrical Pipes, conſiſting of a Trunk, and three Branches

Branches of equal Diameters and Lengths, all lying in the ſame Plane; was ſcrew'd into the Side of a Veſſel fill'd with Water. The Branches were placed at the Diſtances of four, nine, and ſixteen Feet from that End of the Syſtem where the moving Force was apply'd, and beginning with that which lay neareſt to the moving Force, they diſcharged in a given Time Quantities of Water, which were as the Numbers 9, 6, and 5. The Branches having equal Diameters, the Velocities in them were as the Quantities diſcharged; and therefore, the Velocity in a Pipe will be greater or leſs, *cæteris paribus*, as the Pipe is nearer to or farther from the moving Force.

A given Branch at the Diſtance of one Foot from the moving Force diſcharged 20 Ounces of Water in half a Minute, when the Length of

the Trunk was two Feet; and 36 Ounces in the ſame Time, when the Length of the Trunk was encreaſed to eight Feet. And a like Change of Velocity in a leſs Degree, was produced by lengthening any of the other Branches; and therefore, the Velocity in a given Pipe will be greater or leſs, *cæteris paribus*, as any of the other Pipes of the Syſtem is lengthened or ſhortened.

PROPOSITION VII.

IF a given Fluid flows thro' a ſimple Syſtem of Cylindrical Pipes, conſiſting of one Trunk and any Number of Branches; and if any Pipe of the Syſtem be obſtructed or opened, contracted or dilated, the Velocity will be encreaſed or diminiſhed in all the other Pipes of the Syſtem: And the Increaſe

Increase or Diminution of Velocity in any one of them, will be greater or less, cæteris paribus, *as the Pipe is nearer to or farther from the obstructed or opened, contracted or dilated Pipe.*

Since to obstruct or contract a Pipe, is in Effect to lengthen it; and to open or dilate it, is in Effect to shorten it; the first part of this *Proposition*, is true by the preceding: And the second part of it is thus proved. When a Pipe is obstructed or contracted, that part of the moving Force which before this Change generated the Motion destroyed in the obstructed or contracted Pipe, is not lost, but spent in increasing the Motions in the other Pipes which are open, and may be considered as a new Force apply'd to the System at the Place of Obstruction or Contraction, and propagated from thence to all the other

other Pipes of the Syſtem; and therefore, by the laſt *Propoſition*, the Velocities generated in thoſe Pipes by this new Force, will be greater or leſs, as the Pipes are nearer to or farther from the Force, that is, as they are nearer to or farther from the Place of Obſtruction or Contraction. And the contrary muſt happen, when a Pipe is opened or dilated; the Velocities will then be diminiſhed in all the other Pipes, and the Diminution will be greater or leſs, *cæteris paribus*, as the Pipes are nearer to or farther from the Place of Aperture or Dilatation: And therefore the *Propoſition* is true.

Cor. If the ſimple Syſtem be ſo conſtructed, that the Velocities in its Trunk and Branches be reſpectively equal to the Velocities in that principal and thoſe leſſer Trunks of ſuch a compounded Syſtem of Cylindrical Pipes, as is deſcribed

deſcribed in the fourth *Propoſition* or its *Scholium*, thro' which Trunks the Fluid flows into the compounded Syſtem and leſſer Syſtems of which it is compoſed; then, whatever Change is made in the Velocities in any two correſponding Pipes of the two Syſtems, it will produce like Changes of Velocity in all the other correſponding Pipes; and by Conſequence, when the Velocity is leſſened in any one of the ſaid leſſer Trunks of the compounded Syſtem, it will be increaſed in all the others; and its Increaſe will be greater or leſs, *cæteris paribus*, as the Trunks are nearer to or farther from that in which the Velocity is leſſened: And when the Velocity is increaſed in one of the ſaid leſſer Trunks, it will be leſſened in all the reſt: And its Diminution will be greater or leſs, *cæteris paribus*, as they are nearer to or farther from that Trunk

Trunk in which the Velocity is increased.

Proof by EXPERIMENTS.

A System of Cylindrical Pipes had five Branches, A, B, C, D, E, of equal Diameters and Lengths. The Branch A lay nearest to the moving Force, then B, and so on in the Order they are mentioned. The Velocities in these Branches, obtained from the Quantities of Water discharged in a given Time, were as the Numbers $94\frac{2}{3}$, 68, 52, $36\frac{2}{3}$, $19\frac{1}{7}$, when the End of the Trunk was open; and as the Numbers 98, $76\frac{1}{4}$, $70\frac{1}{2}$, $66\frac{1}{2}$, $61\frac{1}{6}$, when the End of the Trunk was shut; and the Differences of the Velocities in the same Pipes, when the End of the Trunk was open and shut, were

$3\frac{1}{3}$, $8\frac{1}{4}$, $18\frac{1}{2}$, $30\frac{1}{6}$, $42\frac{1}{42}$. When the Branch C was ſhut, the Velocities in the Branches A, B, D, E, were as the Numbers $99\frac{1}{2}$, $81\frac{1}{2}$, $43\frac{3}{4}$, $23\frac{1}{3}$; and the Differences between theſe and the Velocities in the ſame Branches, when C was open, were $4\frac{5}{6}$, $13\frac{1}{2}$, $7\frac{1}{2}$, $4\frac{1}{5}$. And the ſame Changes of Velocity, but in a leſſer Degree, will be produced when a Pipe is only contracted.

If the Syſtem originally had had but the four Branches A, B, D, E, and afterwards the Branch C had been added; it is evident from theſe Experiments, that the Velocities in the original Branches would all have been diminiſhed by the Addition of this new Branch; and that the Diminution of Velocity in any of them would have been greater or leſs, as it lay nearer to or farther from the Branch C: But the adding a new Pipe to a Syſtem, will produce like

Changes of Motion in the other Pipes, as the opening or dilating an old Pipe; for by all theſe, there will be a like Abatement of the Force generating the Motion in the other Pipes.

Therefore by theſe Experiments and the *Corollary* of this *Propoſition*, when any Pipe of the ſimple Syſtem, or any of the aforeſaid Trunks of the compounded Syſtem, is obſtructed or opened, contracted or dilated; the Velocity will be encreaſed or diminiſhed in all the other Pipes of the ſimple Syſtem, and all the reſt of the aforeſaid Trunks in the compounded Syſtem; and its Increaſe or Diminution in any one of thoſe Pipes or Trunks, will be greater or leſs, *cæteris paribus*, as it is nearer to or farther from the Pipe or Trunk which is obſtructed or opened, contracted or dilated.

SEC-

SECTION II.

Of Muſcular Motion, the Motion of the Blood, and Reſpiration.

Of Muſcular Motion.

A Muſcle appears to the Eye, to be compoſed of two Parts of different Colours, one red, and the other white. The red is called its fleſhy, and the white its tendinous Part. Some Muſcles are tendinous both at their Origin and Inſertion, and fleſhy only in their Middle; and others are fleſhy at their Origin and in their Middle, and tendinous only at their Inſertion. The fleſhy Part

of a Muſcle is compoſed of Fibres, Membranes, Nerves, Blood-Veſſels, and Lympheducts. The Fibres are ſmall Threads, which are ſhortened when a Muſcle is contracted, and lengthened when it is dilated. The Membranes are thin Skins, which run between the Fibres, are faſtened to them, and tye them together. If a Piece of Fleſh be boiled, till it become very tender, and afterwards be divided and ſubdivided, as far as tne Eye and Hand can go; it will appear, that each minute Fibre in the loweſt Subdiviſion, is intirely ſurrounded by its own particular Membrane. The Membranes, if they be extremely thin, are tranſparent; and if they be thicker, they are of a whitiſh Colour. The Nerves are diſperſed throughout the whole fleſhy Part, as may be gathered from the Pain which is produced any where in that Part by the ſmalleſt Wound.

Wound. It has been a received Opinion, that the Nerves are ſmall Pipes which contain a Fluid, called *Animal Spirits*, drawn off from the Blood in the Brain. But it does not appear from any Experiments, that the Nerves are Pipes; or that ſuch a Fluid as they conceive *Animal Spirits* to be, is ſeparated from the Blood in the Brain; and therefore theſe Opinions are without any juſt Foundation. The Nerves are not only impervious to the ſmalleſt *Stylus*, but when viewed with a Microſcope, evidently appear to have no Cavity. And when we conſider the Manner, in which the Favourers of this Opinion have explained *Muſcular Motion* by *Animal Spirits*; we muſt allow, that ſuch a Fluid is altogether unfit for this Work. For theſe Reaſons, many have thought the Nerves to be ſolid Threads, extended from the Brain to the Muſcles

and

and other Parts of the Body. Sir *Isaac Newton* is of this Opinion, as appears from the following Account he has given of the Nerves, in the 24th *Query* of his *Opticks*. " I sup-" pose that the *Capillamenta* of the " Nerves are each of them solid " and uniform, that the vibrating " Motion of the Ætherial Medium " may be propagated along them " from one End to the other uni-" formly, and without Interruption: " For Obstructions in the Nerves " create Palsies. And that they " may be sufficiently uniform, I " suppose them to be pellucid when " viewed singly, tho' the Reflecti-" ons in their Cylindrical Surfaces " may make the whole Nerve " (composed of many *Capillamen-" ta*) appear opake and white. For " Opacity arises from reflecting " Surfaces, such as may disturb and " interrupt the Motions of this Me-" dium."

" dium." The Blood-Veſſels of a Muſcle are interwoven in the Membranes, and diſtributed throughout its whole fleſhy Part, as appears from its Redneſs, and from the iſſuing out of Blood from a Puncture made any where in it with the fineſt Needle. The Muſcles are ſtocked with Lymphatick Veſſels, as well as the other Parts of the Body.

Having premiſed this ſhort Account of the Structure of a Muſcle, I now proceed to explain its Motion.

Proposition VIII.

MUſcular Motion *is performed by the Vibrations of a very Elaſtick Æther, lodged in the Nerves and Membranes inveſting the minute Fibres of the Muſcles, excited by Heat, the Power of the Will, Wounds, the ſubtile*

subtile and active Particles of Bodies, and other Causes.

It has been found by Observation, that when a Muscle is contracted, its fleshy Fibres are shortened and hardened, without any sensible Change made in its Tendons; that as soon as the Contraction is over, or the contracting Force ceases to act, the shortened and hardened Fibres are lengthened and softened again; that this alternate Motion of Contraction and Dilatation continues in the Hearts of some Animals, especially young ones, for a considerable Time after they are cut out of their Bodies, and laid on a Table; that it generally continues longer in the Hearts of Fish, than in the Hearts of Land-Animals; and that after it has ceased, it may be renewed again by Warmth or the pricking of a Pin, and will continue

nue to be excited by either, eſpecially Warmth, for a little Time, till the Heart wholly loſes its Power of moving; that as the Heart cools by Degrees, ſo its Motion abates gradually, its Contractions and Dilatations growing leſs and leſs frequent and ſtrong, till at laſt they wholly ceaſe; and that the Heat of the Heart is greater, and its Motion more frequent and ſtrong, in an ardent Fever, and the hot Fit of an Ague, than in its natural State.

Hence it appears, that Heat is a remote Cauſe both of the Frequency and Strength of the Motion of the Heart; and conſequently, one of the remote Cauſes of the Motion of a Muſcle.

We find by Experience, that we can move the Muſcles of our Limbs with various Degrees of Force by the ſole Power of the Will; that there is not the leaſt ſenſible Diffe-

rence in point of Time between willing the Motions of the Muſcles, and the Motions themſelves; that Muſcles contracted by the Power of the Will, dilate again at the very Inſtant in which the Soul ceaſeth to exerciſe that Power; and that the Soul loſeth the Power of moving the Muſcles, and perceiving Pain from Wounds made in their fleſhy Parts, when their Nerves are cut quite through, tyed ſtreight, or intirely obſtructed any other Way.

Hence it appears, that the Nerves are the Inſtruments whereby the Will gives Motion to the Muſcles: And it does this, by producing ſome kind of Motion in thoſe Ends of the Nerves which terminate in the Brain, which Motion is propagated from thence thro' their ſolid, pellucid and uniform *Capillamenta* into the Muſcles. For if the Nerves were intirely at Reſt, and no Motion

tion was propagated through them, they could never by the Power of the Will, or any other Cauſe, produce Motion in the Muſcles.

On laying bare the great Muſcle of the hinder Leg of a Dog, and the great Nerve which accompanies the Crural Artery and Vein, I have obſerved, that when the Tendon was wounded, the Dog ſhewed very little Uneaſineſs; but expreſſed great Pain on wounding the fleſhy Part of the Muſcle, and much greater Pain, on wounding, or in the Inſtant of tying the Nerve; that a Contraction of the Muſcle was produced, on wounding its fleſhy Part, and a much ſtronger Contraction on wounding, or in the Inſtant of tying the Nerve; and that after the Nerve was cut quite through, or tyed ſtreight, great Uneaſineſs and Pain with moſt violent Struggles were produced, as often as a new Wound was inflicted, or a

new Ligature made, above the laſt Section or Ligature, in that Part of the Nerve which communicated with the Brain; but that neither Pain nor Contraction of the Muſcle followed, on wounding or tying that Part of it which communicated with the Muſcle and Limb. And I have likewiſe obſerved on trepanning Dogs, and wounding ſeveral Parts of their Brains, that convulſive Motions of the Limbs have ever been produced, on wounding the *Medulla oblongata*, but never on wounding the *Dura Mater*, or Cortical Part.

Hence likewiſe it appears, that the Nerves are the principal Inſtruments of Senſation and Motion; that theſe Effects are ſtronger or weaker, as more or fewer of the nervous *Capillamenta* are tyed or wounded; that theſe Effects are the ſame, in whatever Part of a Nerve

the

the Section or Ligature is made; and that the Soul perceives Pain, and exerts its Power of producing *Muscular Motion*, only at the Origin of the Nerves in the Brain.

The exceeding Quickneſs of this Motion, paſſing from the Brain thro' the *Capillamenta* of the Nerves to the moſt diſtant Muſcles in an Inſtant, and its Ceſſation the very Moment the Cauſe which produced it ceaſes to act, ſhew it to be the vibrating Motion of a very elaſtick Fluid. For it is the Nature of the vibrating Motion of an elaſtick Fluid to be very ſwift, and to ceaſe when the Cauſe which produced it ceaſes to act. A vibrating Motion excited in our Air by the Tremors of Bodies for the Production of Sounds, moves at the Rate of 1142 *Engliſh* Feet in a ſecond Minute of Time, and ceaſes when the Tremors of the Bodies ceaſe.

Now ſince this Motion begun in the Nerves at their Origin, has been proved to be the vibrating Motion of a very elaſtick Fluid; and ſince the other Phænomena of Nature abſolutely require ſuch an elaſtick Fluid, as is the Æther deſcribed by Sir *Iſaac Newton*; and ſince Cauſes are not to be multiply'd without Neceſſity: Therefore it muſt be granted, that this Motion begun in the Nerves at their Origin, is the vibrating Motion of that Æther; the Properties of which, gathered from the Phænomena, are theſe which follow.

This Æther is exceedingly more rare and ſubtile than Air, and exceedingly more elaſtick and active. It readily pervades all Bodies, and by its elaſtick Force is expanded thro' all the Heavens. If it be 700000 times more elaſtick than our Air, it is above 700000 times more rare. Its

elaſtick

elastick Force in Proportion to its Density, is above 490000000000 times greater than the elastick Force of the Air is in Proportion to its Density. It is rarer within Bodies, than in the empty Spaces between them; and in passing from Bodies into empty Spaces, it grows denser and denser by Degrees; and the Increase of its Density at any Distance from the Centre of Gravity of a Body, is as the Quantity of Matter in the Body directly, and the Square of that Distance inversly: And it is rarer within dense Bodies, than within rare Bodies. All Bodies endeavour to recede and go from the denser Parts of it, towards the rarer; and the Force wherewith a Body endeavours to recede, is as the Quantity of Matter in the Body, and the Increase of the Density of the Æther at the Centre of Gravity of the Body, taken together. When it is put into a vibrating Motion by the

Rays of Light, the Will of Animals, or other Causes; its Vibrations or Pulses move swifter than Light, and by Consequence, above 700000 times swifter than Sounds. Its Density and expansive Force, *are both increased in Proportion to the Strength and Vigour of its vibrating Motion; which Motion, like the vibrating Motion of the Air for the Production of Sounds, grows weaker, as the Square of the Distance from the Place, in which it is excited, increases. And* lastly, *its vibrating Motion is regularly propagated thro' Bodies made of uniform dense Matter, but is reflected, refracted, interrupted or disordered by any Unevenness in the Bodies.*

These are the principal Properties, with which this Æther must necessarily be endued; which I thought fit to mention, before I shew the Manner in which it causes the Motion of the Muscles.

When

When by the Power of the Will a vibrating Motion is excited in the Æther, in thoſe Ends of the Nerves which terminate in the Brain; that Motion is in an Inſtant propagated thro' their ſolid and uniform *Capillamenta* to the Membranes of the Muſcles, and excites a like Motion in the Æther lodged within thoſe Membranes; and a vibrating Motion raiſed in the Æther within the Membranes, increaſes its expanſive Force; an Increaſe of that Force ſwells the Membranes; a Swelling of the Membranes cauſes a Contraction of the fleſhy Fibres; and that Contraction, a Motion in the Parts to which the Extremities of the Muſcles are faſtened. Thus the Limbs and other Parts of Animals are moved by their Muſcles, each of which has its two Ends faſtened to two Bones, whereof one is always more moveable than the o-

ther; on which Account, when its fleshy Fibres are shortened by the swelling of the Membranes, the more moveable Bone is drawn towards that which is more fixed, by means of an intervening Joint upon which it turns.

As soon as the Will ceases to act, the vibrating Motion of the Æther caused by that Action ceases; in like manner as the Pulses of the Air causing Sounds cease, on a Cessation of the Tremors of sonorous Bodies, by which they are excited; and a Cessation of the vibrating Motion of the Æther, causes a Diminution of its expansive Force; and a Diminution of that Force, gives an Opportunity to the dilated Membranes to contract, by the attractive Powers of their Parts, and thereby to lengthen the fleshy Fibres. Another Cause of the lengthening of the fleshy Fibres and Dilatation of

of a Muſcle, is a vibrating Motion, excited in the Æther lodged in the fleſhy Fibres by their Contraction: For that vibrating Motion will increaſe the expanſive Force of the Æther, and that increaſed Force will lengthen the Fibres, the very Inſtant the Cauſe which contracted them ceaſes to act. Theſe two Forces added together, make the whole Force whereby a contracted Muſcle is dilated: For the Experiments above-mentioned fully prove, that the Soul has no immediate Power over the fleſhy Fibres. Thus the Muſcles of Animals are moved by the Æther, when put into a vibrating Motion by the Power of the Will.

I have ſhewn that Heat, Punctures or Wounds, and Ligatures on the Nerves in the Inſtant they are made, have a Power of contracting the Muſcles: And from the Effects of

vomiting and purging Medicines, and ſome Poiſons, we learn, that the ſubtile and active Particles of ſome Bodies have a like Power: But ſince all theſe Things, however different they are in themſelves, do notwithſtanding produce the ſame Effect which the Will does, they muſt do it in the ſame Manner, that is, by exciting a vibrating Motion in the Æther within the Nerves and Membranes of the Muſcles. And therefore the *Propoſition* is true.

Cor. 1. The Motion of the Muſcles becomes weak, either from too weak a vibrating Motion of the Æther in their Membranes and Fibres; or an Unfitneſs in the Membranes and Fibres to be moved with Vigour by a due Degree of that vibrating Motion. The vibrating Motion excited by a given

Force

Force becomes weak, when the Æther becomes rare; and the Æther becomes rare, when the Membranes and Fibres become denſe, from Moiſture ſoaking into their Pores, from Compreſſion, or other Cauſes. And the Membranes and Fibres become unfit to be moved with Vigour, when they are rendered ſtiff by Age, too hard Labour, or other Cauſes.

Cor. 2. Muſcles grow larger and ſtronger by moderate Exerciſe: For the expanſive Force of the Æther muſt be encreaſed, before it can move the Muſcles; and a frequent Increaſe of this Force in Muſcles much moved, muſt of Neceſſity increaſe both their Magnitudes and Strengths. Hence labouring Perſons have larger and ſtronger Muſcles, than Perſons who lead a ſedentary and inactive Life.

Cor.

Cor. 3. The Blood moving thro' a Muſcle, is preſſed forward by the Force of its Contraction; but after a Muſcle is contracted, if it be kept in that State by the conſtant Action of the Force which contracted it, leſs Blood will flow through it in a given Time than did before: For the Blood-Veſſels interwoven in the Membranes, are compreſſed and contracted by the ſwoln Membranes and ſhortened and hardened Fibres: And this Contraction of the Veſſels, while it is exerting, preſſes the Blood forward; but afterwards hinders the Blood from flowing through the Muſcle in that Quantity it did before. Hence Exerciſe performed by the Motion of the Muſcles, accelerates the Motion of the Blood; and Cramps and other permanent Convulſions retard it.

Cor.

Cor. 4. The Magnitude of a Muſcle may be but little altered by its Contraction: For if the Contraction of the fleſhy Fibres be nearly equal to the Swelling of the Membranes, its Magnitude will continue much the ſame, though its Figure be changed.

Cor. 5. The Forces of correſponding Muſcles in healthful Bodies, are meaſured by their Weights, and the Strengths of the vibrating Motions of the Æther in them, taken together.

Cor. 6. If a great Increaſe of the vibrating Motion of the Æther in the Nerves and Membranes of one Part of a Body, be attended with a Diminution of its vibrating Motion in the Nerves and Membranes of other Parts; then it may be in the Power

Power of Art to quiet a Disturbance in one Part, by raising a stronger Disturbance in another: As by Blisters, Cauteries, and other powerfully stimulating Bodies, applied to one Part of a Human Body, we often relieve Pain, and quiet convulsive Motions in other Parts of it.

Of

Of the Motion of the Blood.

Proposition IX.

THE Blood moves in the Arteries and Veins with a kind of Circular Motion.

Harvey has proved this from Experiments and Obſervations: For he has ſhewn, that the Blood flows out of the Trunk of the *Vena cava*, into the right Auricle of the Heart; out of that, into the right Ventricle; thence, thro' the Lungs, into the left Auricle and Ventricle; out of the left Ventricle, into the *Aorta*; whoſe Branches convey it to all Parts of the Body, and pour it into

the ſmalleſt Branches of the Veins; out of which it paſſes into Branches ſtill larger, till at laſt, by the *Vena cava* it is brought back to the Heart. And this Motion of the Blood from and to the Heart, is called its *Circulation*, or *Circular Motion*.

The Heart and Arteries act upon the Blood, in generating and keeping up its Motion, in the following Manner. When the Auricles are filled with Blood by the Veins, the right Auricle by the *Vena cava*, and the left by the Pulmonary Vein, they both contract at one and the ſame Time, and preſs the Blood which they contain into the Ventricles; and when the Ventricles are filled with Blood, they likewiſe contract at one and the ſame Time, and preſs the Blood which they contain into the Arteries; the right Ventricle into the Pulmonary Artery,

tery, and the left into the *Aorta*. The Arteries are dilated by the Blood, forcibly preſſed into them by the Ventricles; and as ſoon as the Ventricles are emptied, and their Contraction is over, the dilated Arteries contract, and preſs the Blood forward into the Veins. And thus the Motion of the Blood is generated and kept up, by the Forces of the Heart and Arteries.

The Blood is kept from regurgitating, by the Valves of the Heart and Veins. The Valves at the Entrance of the Auricles into the Ventricles, open when the Auricles contract, and permit the Blood to flow into the Ventricles; and ſhut when the Ventricles contract, and prevent its Return into the Auricles. The Valves at the Origins of the *Aorta* and Pulmonary Artery, open when the Ventricles contract, and ſuffer the Blood to flow

into the Arteries; and ſhut when the Arteries contract, and hinder it from flowing back into the Ventricles. And the Valves of the Veins open to let the Blood move forward towards the Heart; and ſhut to prevent its Return into the Arteries.

Cor. 1. The two Ventricles of the Heart throw out equal Quantities of Blood in each Syſtole: For they always contract together; and therefore if they threw out unequal Quantities, more or leſs Blood would flow into the Lungs, than flows out of them, in a given Time: Which muſt of Neceſſity ſoon put an End to Life.

Cor. 2. As much Blood flows thro' each Ventricle of the Heart, and thro' the Lungs in any Time, as flows thro' all the reſt of the Body in that Time.

Cor.

Cor. 3. The Arteries have a Pulſe, and the Veins no Pulſe: For the Arteries have a ſtronger muſcular Coat than the Veins, on account of their ſuſtaining a greater Preſſure againſt their Sides from the Blood forced into them by each Syſtole of the Heart; and they ſuſtain a greater Preſſure againſt their Sides than the Veins, from a greater Quantity of Blood lying before them, which gives a greater Reſiſtance to the Blood forced into them by the Heart. Now the Sides of both Arteries and Veins being ſoft and dilatable, it is evident, that the whole Syſtem of Veſſels muſt ſwell, when Blood is forcibly preſſed into it by the Heart in its Syſtole; and endeavour to contract again, when the Force of the Heart ceaſes to act in its Diaſtole: But when the Arteries and Veins begin to contract after every Syſtole of the Heart, the

Arteries,

Arteries, by the greater Strength of their Muſcular Coat, overpower the Veins; and by preſſing the Blood into them, hinder them from contracting: Therefore the Arteries by dilating and contracting, have a Pulſe; and the Veins for want of this alternate Motion, have no Pulſe.

Proposition X.

THE mean Velocity of the Blood is leſs in the Sum of the Branches of both Arteries and Veins, than the Velocity in their reſpective Trunks; and the Velocity is leſs in the Veins, than in their correſponding Arteries.

For it has been found by meaſuring the Veſſels, that the Branches of an Artery or Vein taken all together,

gether, are wider than the Trunk out of which they ariſe; and that the Veins are wider than their correſponding Arteries: And therefore the *Propoſition* is true, by the 5*th Corollary* of the 5*th Propoſition*.

Cor. 1. Hence it appears, that the Velocity of the Blood is continually leſſened in the Arteries from their Trunks to their ſmalleſt Branches; and increaſed continually in the Veins from their ſmalleſt Branches to their Trunks: And by Conſequence, that the Velocity is leaſt in the laſt and ſmalleſt Branches of the Arteries and Veins.

Cor. 2. Since the Velocity of the Blood is leaſt in the ſmalleſt Branches of the Arteries and Veins; it neceſſarily follows, that the Blood will be more liable to be obſtructed by Cold and other Cauſes, in its Courſe thro'

thro' those Vessels, than thro' any others.

Proposition XI.

THE Velocity of the Blood in one and the same Artery or Vein, is the same both in the Systole and Diastole of the Heart; when the Arteries are dilated, and when they are contracted.

For since the Veins have no Pulse, the Blood must necessarily flow thro' them with the same Velocity when the Arteries are dilated, and when they are contracted; which it could not do, if it moved faster through the Arteries when they are dilated, than when they are contracted; in the Systole of the Heart, than in its Diastole: And therefore the *Proposition* is true.

Cor.

Cor. 1. Hence it appears, that while the progreſſive Motion of the Blood continues the ſame; the Force which generates this Motion, muſt by its conſtant Action continually generate as much Motion as is deſtroyed by the Reſiſtance of the internal Surface of the whole Syſtem of Blood-Veſſels; otherwiſe it would be impoſſible, that the Velocities of the Blood in the ſame Veſſels ſhould be the ſame in the Syſtole of the Heart, and in its Diaſtole; when the Arteries are dilated, and when they are contracted.

This will not appear ſtrange when we conſider, that there are other Motions in Nature which are uniform, notwithſtanding the conſtant Action of a given moving Force. Of this kind is the Motion of a Ship, generated by a Wind blowing conſtantly and uniformly; which Motion is at firſt accelerated,

till as much Motion is continually communicated to the Water and Air by the Ship moving along; as is generated in it by the constant and uniform Action of the Wind: And after that, it continues uniform, notwithstanding the constant Action of the Wind. Of this kind also, is the Motion of a Body descending in Water; which Motion is accelerated, till the Motion communicated to the Water by the descending Body, becomes equal to the Motion generated in the Body by the constant and uniform Action of its Weight in Water; and after that, the Motion continues uniform, notwithstanding the constant Action of this Weight.

Proposition XII.

THE Velocities of the Blood in the correſponding Blood-Veſſels of healthful Bodies ſituated alike with reſpect to the Horizon, are in the ſubduplicate Ratios of the Diameters of thoſe Veſſels, that is, V . v : : $\surd$D. $\surd$d.

For from Anatomy and the Similarity of the correſponding Parts of human Bodies we learn, that their Syſtems of Blood-Veſſels have the ſame Number of correſponding Veſſels; and that correſponding Veſſels have like Situations and Capacities, in Bodies ſituated alike with reſpect to the Horizon, that is, any two correſponding Veſſels are ſituated alike with reſpect to the reſt of the

the Veſſels, and their Capacities are as the Capacities of the whole Syſtems.

The Forces of the Hearts of human Bodies are as their Weights, and as the Strengths of the vibrating Motions of the Æther in their Nerves and Membranes, taken together, by *Cor.* 5. *Prop.* 8. But the Strengths of the vibrating Motions of the Æther, ſetting aſide the Power of the Soul and other diſturbing Cauſes, are as the Heats of the Hearts; and the Heats of the Hearts, as the Heats of the Blood; and the Heats of the Blood are much the ſame in all healthful Bodies, as I have found by the Thermometer: And therefore, ſetting aſide the Power of the Soul and other diſturbing Cauſes, the Forces of the Hearts are as their Weights. The Weights of the Hearts of a ſtrong Man and a Child newly born,

were as 16 and 1; the Diameters of their *Aortas* as 2 and 1; and the Lengths of their Bodies as 4 and 1: Now ſince the Lengths of correſponding Blood-Veſſels are as the Lengths of the Bodies, and the Diameters of correſponding Veſſels as the Diameters of the *Aortas* in Bodies ſituated alike with reſpect to the Horizon; it is evident from this Inſtance, that the Weights of the Hearts are as the Capacities of correſponding Veſſels, or as the Capacities of the whole Syſtems, in Bodies ſituated alike with reſpect to the Horizon: And therefore the Forces of the Hearts, when they are not diſturbed by the Power of the Soul or other Cauſes, are as the Capacities of correſponding Blood-Veſſels, or as the Capacities of the whole Syſtems in Bodies ſo ſituated; and the Forces generating the Motions in correſponding Veſſels, are

as the Capacities of those Vessels; and by Consequence, as the whole Forces of their Hearts. Moreover if it be considered, that the System of Blood-Vessels swells or contracts as the Force of the Heart is increased or lessened by the Power of the Soul, Heat or Cold, or other Causes; and on the contrary, that the Force of the Heart is increased or lessened, as the System swells or contracts by Heat or Cold; no Doubt can be made, but that the Forces of the Hearts are ever proportional to the Capacities of their respective Systems of Blood-Vessels; and that the Forces generating the Motions in corresponding Vessels, are as the whole Forces of their Hearts in Bodies situated alike with respect to the Horizon.

And these Things being true, the *Proposition* is true, by the *First Corollary* of the *Fourth Proposition*.

Cor.

Cor. 1. Hence it appears, that the Velocity of the Blood increaſes continually from the Birth, till Bodies are arrived at their full Lengths; and afterwards, it increaſes or leſſens in the ſame Bodies, as their Syſtems of Blood-Veſſels ſwell or contract, either from an Increaſe or Diminution of the Quantity, or a Diminution or Increaſe of the Denſity of the Blood.

Cor. 2. When healthful Bodies are ſituated alike with reſpect to the Horizon, and their Hearts are free from the Influences of diſturbing Cauſes; the Velocities of the Blood in correſponding Blood-Veſſels, are in Ratios compounded of the ſubquadruplicate Ratios of the Quantities of Blood contained in their whole Syſtems of Blood-Veſſels directly, and of the ſubquadruplicate Ratios of the Lengths of the Bodies inverſly. For the Heat of the

Blood

Blood is the ſame in Bodies under theſe Circumſtances, as I have found by the Thermometer, and conſequently its Denſity is given; but the Denſity of the Blood being given, the Capacities of correſponding Blood-Veſſels will be as the Quantities of Blood contained in them, or as the Quantities contained in the whole Syſtems; therefore, putting Q and q for the Quantities contained in two whole Syſtems, D and d for the Diameters of any two correſponding Blood-Veſſels in thoſe Syſtems, and L and l for the Lengths of the Bodies, D^2L will be to d^2l as Q to q, the Lengths of correſponding Blood-Veſſels in different Bodies being as the Lengths of the Bodies themſelves: So then $\sqrt{D}$ is to $\sqrt{d}$ as $\sqrt[4]{\frac{Q}{L}}$ to $\sqrt[4]{\frac{q}{l}}$: But by this *Propoſition*, $V . v :: \sqrt{D} . \sqrt{d}$; And therefore in Bodies under the

Cir-

Circumſtances mentioned in this *Corollary*, $V . v :: \frac{Q^{\frac{1}{4}}}{L^{\frac{1}{4}}} . \frac{q^{\frac{1}{4}}}{l^{\frac{1}{4}}}$.

Cor. 3. If two healthful Bodies of equal Lengths, or one and the ſame Body at two different Times, be ſituated alike with reſpect to the Horizon, and their Hearts be free from the Influences of diſturbing Cauſes; the Velocities of the Blood in any two correſponding Blood-Veſſels of the two Bodies, or in any one and the ſame Blood-Veſſel of the ſame Body at two different Times, will be in the ſubquadruplicate Ratios of the whole Quantities of Blood contained in the two Bodies, or in the ſame Body at thoſe different Times, by the laſt *Corollary*: If L=l; then will $V . v :: Q^{\frac{1}{4}} . q^{\frac{1}{4}}$.

That the Velocities of the Blood as they are expreſſed in this *Corol-*

lary, may be found out more eaſily, I have added the following Table: Which in the two Columns under Q, contains different Quantities of Blood; and in the two Columns under V, different Velocities expreſſed in the biquadrate Roots of thoſe Quantities. For Inſtance, if the Quantities of Blood in two different Bodies of equal Lengths, or in one and the ſame Body at two different Times, be as 20 and 18; the Velocities in the correſponding Blood-Veſſels of the two Bodies, or in the ſame Blood-Veſſel of the ſame Body at different Times, will be as the Numbers 21147 and 20598, if the Bodies be under the Circumſtances ſuppoſed in this *Corollary*.

Q	V	Q	V
1	10000	26	22581
2	11892	27	22795
3	13161	28	23003
4	14142	29	23206
5	14953	30	23403
6	15650	31	23596
7	16266	32	23784
8	16818	33	23968
9	17320	34	24147
10	17783	35	24323
11	18211	36	24495
12	18612	37	24663
13	18988	38	24828
14	19343	39	24990
15	19680	40	25149
16	20000	41	25304
17	20305	42	25457
18	20598	43	25607
19	20878	44	25755
20	21147	45	25900
21	21407	46	26043
22	21657	47	26183
23	21899	48	26321
24	22134	49	26457
25	22361	50	26591

Cor. 4. If the Diameters of corresponding Blood-Veſſels be in the ſubduplicate Ratios of the Lengths of the Bodies; the Velocities in thoſe Veſſels will be in the ſubquadruplicate, and the Capacities of the whole Syſtems in the duplicate Ratios of the Lengths of the Bodies. If $D . d :: \sqrt{L} . \sqrt{l}$; then will $V . v :: L^{\frac{1}{4}} . l^{\frac{1}{4}}$, and $D^2 L . d^2 l :: L^2 . l^2$.

From the Inſtance mentioned in the Proof of this *Propoſition* it is evident, that theſe Proportions of the Diameters of correſponding Blood-Veſſels, and of the Capacities of the whole Syſtems, obtain in ſome Bodies when ſituated alike with reſpect to the Horizon; and it is as certain, that they do not obtain in all Bodies ſo ſituated; becauſe of Bodies of the ſame Length, ſome, from a different Uſe of the Non-naturals or other Cauſes, have larger Blood-

Blood-Veſſels than others: Now if theſe Proportions be obſerved in the moſt perfect and beſt proportioned Bodies, they will likewiſe obtain in all Bodies of different Lengths, taking thoſe of each Length one with another, when they are ſituated alike with reſpect to the Horizon, that is, the mean Diameters of correſponding Blood-Veſſels of Bodies of different Lengths ſo ſituated, each Mean being taken from a conſiderable Number of Diameters of correſponding Blood-Veſſels of Bodies of the ſame Length, will be in the ſubduplicate; and the mean Capacities of the whole Syſtems in the duplicate Ratios of the Lengths of the Bodies: Otherwiſe there could be no Regularity, no Uniformity preſerved in the Species.

Lengths in Inches.	Velocities.	Capacities of the Syſtems.
72	2913	5184
66	2850	4356
60	2783	3600
54	2711	2916
48	2632	2304
42	2546	1764
36	2449	1296
30	2340	900
24	2214	576
18	2060	324

This Table contains in the firſt Column, the Lengths of Bodies in Inches; in the ſecond, the true or mean Velocities of the Blood in the correſponding Blood-Veſſels of Bodies ſituated alike with reſpect to the Horizon; and in the third, the true or mean Capacities of the whole Syſtems of Blood-Veſſels of Bodies of thoſe Lengths. For Inſtance,

ſtance, the true or mean Velocities of the Blood in the correſponding Blood-Veſſels of Bodies alike ſituated, whoſe Lengths are 72 and 36, are as the Numbers 2913 and 2449; and the true or mean Capacities of their whole Syſtems of Blood-Veſſels, as the Numbers 4 and 1.

Cor. 5. If the Diameters of correſponding Blood-Veſſels of Bodies ſituated alike with reſpect to the Horizon, be as the n Power of the Lengths of the Bodies; the Velocities in thoſe Veſſels will be as the $\frac{n}{2}$ Power; and the Capacities of the whole Syſtems, and Quantities of Blood if the Forces of the Hearts are not diſturbed, as the $2n+1$ Power of the Lengths of the Bodies, that is, $V . v :: L^{\frac{n}{2}} . l^{\frac{n}{2}}$, and $D^2 L . d^2 l :: L^{2n+1} . l^{2n+1}$, and $Q . q :: L^{2n+1} . l^{2n+1}$ if $D^2 L . d^2 l :: Q . q$.

For

For Example, If the Diameters of correſponding Veſſels be in the ſubtriplicate Ratios of the Lengths of the Bodies, and the Lengths of the Bodies be 72 and 18; the Velocities will be as the Numbers 63 and 50; and the Capacities of the Syſtems and Quantities of Blood, as the Numbers 10 and 1.

Proposition XIII.

THE *Velocities of the Blood in the correſponding Blood-Veſſels of healthful Bodies ſituated alike with reſpect to the Horizon, are in Ratios compounded of the ſimple Ratios of the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Syſtole directly, and of the duplicate Ratios of the Diameters of thoſe Veſſels and of the ſimple Ratios of the* Times

Times of one Syſtole inverſly. If K, k *denote the Magnitudes of the Quantities of Blood thrown out of the Hearts of two Bodies in one Syſtole, and* T, t *the Times of one Syſtole; I ſay, that*
$$V . v :: \frac{K}{D^2T} . \frac{k}{d^2t}.$$

For the Velocities of the Blood in any two correſponding Blood-Veſſels, are directly as the Spaces deſcribed by the Blood in the Times of one Syſtole, and inverſly as thoſe Times: But the Spaces deſcribed by the Blood in the Times of one Syſtole, are as the Magnitudes of the Quantities of Blood which flow into thoſe Veſſels in the Times of one Syſtole apply'd to the Orifices or Squares of the Diameters of the Veſſels; and the Magnitudes of thoſe Quantities are as the Magnitudes of the Quantities thrown out of their Hearts in one Syſtole, if the Bodies be ſituated alike with reſpect

to the Horizon: And therefore, the Velocities in the correſponding Blood-Veſſels of Bodies ſo ſituated, are in Ratios compounded of the ſimple Ratios of the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Syſtole directly, and of the duplicate Ratios of the Diameters of the Veſſels and of the ſimple Ratios of the Times of one Syſtole inverſly: Which was to be proved.

Cor. 1. If the Magnitudes of the Quantities of Blood thrown out of the Hearts of two Bodies in one Syſtole, be as the Capacities of any two correſponding Blood-Veſſels; the Velocities in thoſe Veſſels will be as the Lengths of the Bodies directly, and as the Times of one Syſtole of their Hearts inverſly. If $K . k :: D^2 L . d^2 l$; then will $V . v :: \frac{L}{T} . \frac{l}{t}$.

This

This *Corollary* obtains in Bodies which are ſituated alike with reſpect to the Horizon, and whoſe Hearts are not influenced by diſturbing Cauſes: For the Hearts of Bodies under theſe Circumſtances, will throw out in each Syſtole Quantities of Blood whoſe Magnitudes are equal to the Capacities of their Ventricles; but the Capacities of the Ventricles are as the Magnitudes of the Hearts; and the Magnitudes of the Hearts are as their Weights; (for I have found their Denſities to be ſo nearly equal, that their Differences may be neglected) and the Weights of the Hearts are as their Forces; and their Forces as the Capacities of correſponding Blood-Veſſels by the *Proof* of the 12*th Propoſition*; and therefore $K.k :: D^2L.d^2l$.

Cor. 2. The true Times of one Syſtole of the Hearts of regular and

well-proportioned Bodies of different Lengths, and the mean Times of one Systole of the Hearts of all Bodies of different Lengths, each Mean being taken from a considerable Number of Bodies of the same Length, are, when the Bodies are situated alike with respect to the Horizon, and their Hearts are free from the Influences of all disturbing Causes, as the biquadrate Roots of the Cubes of the Lengths of the Bodies, that is, $T . t :: L^{\frac{3}{4}} . l^{\frac{3}{4}}$. For in these Cases, $V . v :: L^{\frac{1}{4}} . l^{\frac{1}{4}}$ by the 4*th Corollary* of the 12*th Proposition*, and $V . v :: \frac{L}{T} . \frac{l}{t}$ by the preceding *Corollary* of this *Proposition*; and therefore $L^{\frac{1}{4}} . l^{\frac{1}{4}} :: \frac{L}{T} . \frac{l}{t}$; whence $T . t :: L^{\frac{3}{4}} . l^{\frac{3}{4}}$.

PRO-

PROPOSITION XIV.

THE Velocities of the Blood in the corresponding Blood-Vessels of healthful Bodies situated alike with respect to the Horizon, are in Ratios compounded, of the simple Ratios of the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Systole, and of the simple Ratios of the Numbers of their Pulses in a given Time, directly; and of the duplicate Ratios of the Diameters of those Vessels inversly. If P, p *denote the Numbers of Pulses in a given Time of two healthful Bodies situated alike with respect to the Horizon; then will*

$$V . v :: \frac{KP}{D^2} . \frac{kp}{d^2}.$$

Proof

Proof by EXPERIMENTS.

I Took the Pulſes in a Minute, and meaſured the Lengths, of a great Number of Bodies; I took the Pulſes when the Bodies were ſitting, that they all might be ſituated alike with reſpect to the Horizon; and in the Morning before Breakfaſt, that their Hearts might be as free as poſſible from the Influences of all diſturbing Cauſes: And when I had got a very large Stock of Obſervations, I took the Means of the Pulſes, each Mean from a conſiderable Number of Bodies of the ſame Length; and found thoſe Means to be nearly as the biquadrate Roots of the Cubes of the Lengths of the Bodies inverſly, that is, nearly as the mean Times of a Syſtole of their Hearts inverſly, by *Cor.* 2. *Prop.* 13.

And

And ſince the mean Numbers of Pulſes in a Minute of all Bodies, are the true Numbers of Pulſes in a Minute of ſingle Bodies of the ſame Lengths which are regular and well-proportioned; the Numbers of Pulſes in a Minute of regular and well-proportioned Bodies taken ſingly, will likewiſe be as the biquadrate Roots of the Cubes of their Lengths, that is, as the Times of a Syſtole of their Hearts inverſly, by the aforeſaid *Corollary*. Now ſince in theſe Inſtances, the Numbers of Pulſes in a Minute are inverſly as the Times of one Syſtole, and ſince there is no apparent Reaſon why this Proportion ſhould not be univerſal; I ſhall therefore conclude, that it is ſo: And that in all Bodies, $P.p::\frac{1}{T}.\frac{1}{t}$: But by the laſt *Propoſition*, $V.v::\frac{K}{D^2T}.\frac{k}{d^2t}$: And therefore, $V.v::\frac{KP}{D^2}.\frac{kp}{d^2}$.

To

Ages in Years.	Lengths in Inches.	Pulses from Observation.	Pulses by the Theory.
	72	65	65
	68	67	68
	60	72	74
14	55	77	79
12	51	82	84
9	46	90	91
6	42	97	97
3	35	113	112
2	32	120	119
1	28	126	132
½	25	137	144
0	18	150	184

To shew the near Agreement of the Pulses from Observation with the Pulses by the Theory, I have added this Table; which contains in the first Column, the mean Ages of growing Bodies when they arrive at the Lengths in Inches standing over

over againſt them in the ſecond Column; in the third Column, the mean Numbers of Pulſes in a Minute in the Morning before Breakfaſt when the Bodies were ſitting; and in the fourth Column, the Numbers of Pulſes in a Minute ſuppoſing them to be inverſly as the biquadrate Roots of the Cubes of the Lengths of the Bodies, and making 65 the firſt Number in the third Column found from Obſervation, the firſt Number in this. In making this Table, I neglected Fractions which were not near an Unit, and put an Unit inſtead of thoſe which were.

It may be obſerved, that the Number of Pulſes from Obſervation of a Child newly born, falls conſiderably ſhort of the Number of Pulſes by the Theory. The Pulſe of a Child newly born can ſcarcely be perceived. I have often try'd to

feel it and count its Numbers in a given Time, but never ſucceeded: Once I reckon'd 150 Beats or more in a Minute in a Child ſeven or eight Days old. And therefore, though I have made 150 the mean Number, yet I cannot ſay, that it is the true mean Number; but ſuppoſing it to be ſo, its falling ſo much ſhort of the Theory, may in ſome meaſure be accounted for from the Nature of that Cauſe which diſpoſes Infants to ſleep almoſt perpetually; which Cauſe, by weakening the vibrating Motion of the Æther in the Nerves and Membranes of the Heart, muſt neceſſarily make the Pulſe ſlower than it otherwiſe would be.

Cor. 1. The Velocities of the Blood in the correſponding Blood-Veſſels of Bodies, which are ſituated alike with reſpect to the Horizon, and whoſe Hearts are free from

the Influences of all diſturbing Cauſes, are in Ratios compounded of the Ratios of the Lengths of the Bodies and of the Numbers of their Pulſes in a given Time: For in this Caſe, the Magnitudes of the Quantities of Blood thrown out of the Ventricles of their Hearts in one Syſtole, are as the Capacities of correſponding Blood-Veſſels, that is, K. k :: D^2L. d^2l; and therefore, V. v :: LP. lp.

Cor. 2. The Velocities of the Blood in the correſponding Blood-Veſſels of healthful Bodies of equal Lengths, when they are ſituated alike with reſpect to the Horizon, and their Hearts are free from the Influences of all diſturbing Cauſes, will be as the Numbers of their Pulſes in a given Time, by the laſt *Corollary*; by which, when L = l, V. v :: P. p. The ſame Proportion

will obtain in one and the ſame Body at two different Times, if the Body at thoſe Times be ſituated alike with reſpect the Horizon, and its Heart be free from the Influences of all diſturbing Cauſes: For the ſame Syſtem having different Magnitudes at different Times, may be conſidered as two Syſtems of equal Lengths.

Cor. 3. The Quantities of Blood, which in a given Time flow thro' the correſponding Blood-Veſſels of healthful Bodies ſituated alike with reſpect to the Horizon, when their Hearts are free from the Influences of all diſturbing Cauſes, are in Ratios compounded of the Ratios of the Quantities of Blood contained in their whole Syſtems of Blood-Veſſels, and of the Numbers of their Pulſes in a given Time. For the Quantities of Blood which flow thro' correſponding Veſſels in a given

ven Time, are as the Squares of the Diameters of the Veſſels, and the Velocities of the Blood flowing thro' them, taken together, that is, as $D^2 V$ and $d^2 v$, or as KP and kp, becauſe $V . v :: \frac{KP}{D^2} . \frac{kp}{d^2}$, by this *Propoſition*; But K. k :: Q. q, the Denſity of the Blood being given: And therefore, the Quantities of Blood which flow thro' correſponding Blood-Veſſels in a given Time, will be as QP and qp.

The Quantities of Blood of a tall ſtrong Man and of a Child newly born, are as the Numbers 16 and 1; and the Numbers of the Man's Pulſes in a Minute in the Morning, when he is ſitting, is 65 by the foregoing Table; and if the Number of the Child's Pulſes in a Minute be 150, as it is there put down; the Quantities of Blood flowing thro' the Lungs of the Man and of the Child

Child in a given Time, will be as the Numbers 104 and 15. According to *Tabor*, each Ventricle of the Heart of the Man can contain 1500 Grains of Blood; and consequently, when the Heart is not influenced by disturbing Causes, will throw out 5850000 Grains in an Hour: And each Ventricle of the Heart of the Child will throw out 843750 Grains in the same Time. Therefore, about 835 and 120 *Averdupois* Pounds of Blood will pass through the Lungs of the Man and of the Child in an Hour.

If the Quantities of Blood of strong well-proportioned Bodies be $\frac{1}{12}$ Part of their Weights, (as they are according to *Glisson* and *Tabor*) and if the Weights of a tall strong well-proportioned Man and a strong well-proportioned Child newly born, be 168 and $10\frac{1}{2}$ *Averdupois* Pounds; the whole Quantities of their

their Blood will be 14 Pounds and $\frac{7}{8}$ of a Pound: And consequently, as much Blood as is contained in the Body, will flow $59\frac{1}{2}$ times thro' the Lungs of the Man, and 137 times thro' the Lungs of the Child, in an Hour.

Cor. 4. If Bodies be situated alike with respect to the Horizon, and their Hearts be free from the Influences of all disturbing Causes; the Quantities of Blood which flow through their Lungs or other corresponding Parts in a given Time in Proportion to the whole Quantities of Blood contained in their Bodies, will be as the Numbers of their Pulses in a given Time: For the Quantities of Blood which flow through corresponding Blood-Vessels in a given Time, are as Q P and q p, by the last *Corollary*; but $\frac{QP}{Q}$ and $\frac{qp}{q}$, are as P and p.

PRO-

PROPOSITION XV.

I*F Bodies be situated alike with respect to the Horizon; the Diameters of corresponding Blood-Vessels will be proportional to the fifth Roots of the Squares of the Products made by the Magnitudes of the Quantities of Blood thrown out of their Hearts in one Systole, and the Numbers of their Pulses in a given Time, that is,* $D . d :: \overline{KP}^{\frac{2}{5}} . \overline{kp}^{\frac{2}{5}}$: *The Velocities in corresponding Vessels will be as the fifth Roots of the said Products, that is,* $V . v :: \overline{KP}^{\frac{1}{5}} . \overline{kp}^{\frac{1}{5}}$: *And the Forces of their Hearts as the fifth Roots of the fourth Powers of them, and as the Lengths of the Bodies taken together, that is,* $F . f :: \overline{KP}^{\frac{4}{5}} \times L . \overline{kp}^{\frac{4}{5}} \times l$.

For

For the Forces of the Hearts of Bodies situated alike with respect to the Horizon, are as the Capacities of corresponding Blood-Vessels, by the Proof of the 12*th Proposition*, and the Lengths of corresponding Blood-Vessels are as the Lengths of the Bodies, wherefore $F.\ f.\ D^2 L.\ d^2 l$: And the same Forces by *Cor*. 4. *Prop*. 4. are in Ratios compounded of the duplicate Ratios of the Velocities, and of the simple Ratios of the Diameters of those Vessels and of the Lengths of the Bodies, that is, $F.\ f :: V^2 D L.\ v^2 d l$: But by the 14*th Proposition*, $V^2.\ v^2.\ \frac{\overline{KP}^2}{D^4}.\ \frac{\overline{kp}^2}{d^4}$; and therefore, $F.\ f :: \frac{\overline{KP}^2 \times L}{D^3}.\ \frac{\overline{kp}^2 \times l}{d^3}$: And comparing this Proportion of the Forces with the first, we shall have $D^2 L.\ d^2 l :: \frac{\overline{KP}^2 \times L}{D^3}.\ \frac{\overline{kp}^2 \times l}{d^3}$, whence $D.\ d :: \overline{KP}^{\frac{2}{5}}.\ \overline{kp}^{\frac{2}{5}}$.

Extracting the Square Root of the laſt Analogy, $\sqrt{D}.\ \sqrt{d} :: \overline{KP}^{\frac{1}{5}}.\ \overline{kp}^{\frac{1}{5}}$: But $V.\ v :: \sqrt{D}.\ \sqrt{d}$, by the 12*th Propoſition*: And therefore $V.\ v :: \overline{KP}^{\frac{1}{5}}.\ \overline{kp}^{\frac{1}{5}}$.

And ſquaring the ſame Analogy, $D^2.\ d^2 :: \overline{KP}^{\frac{4}{5}}.\ \overline{kp}^{\frac{4}{5}}$: But $F.\ f :: D^2L.\ d^2l$: And therefore, $F.\ f :: \overline{KP}^{\frac{4}{5}} \times L.\ \overline{kp}^{\frac{4}{5}} \times l$.

Cor. 1. If two Bodies of equal Lengths, or one and the ſame Body at two different Times, be ſituated alike with reſpect to the Horizon; the Forces of the Hearts of the two Bodies, or of the Heart of the ſame Body at thoſe Times, will be proportional to the fifth Roots of the fourth Powers of the Products made by the Magnitudes of the Quantities of Blood thrown out in one Syſtole, and the Numbers of Pulſes in

in a given Time. If L=l; then will $F.\, f :: \overline{KP}^{\frac{4}{7}}.\, \overline{kp}^{\frac{4}{7}}$.

Cor. 2. If two Bodies of equal Lengths, or one and the ſame Body at two different Times, be ſituated alike with reſpect to the Horizon; and if the Hearts of the two Bodies, or the Heart of the ſame Body at thoſe Times, throw out in one Syſtole Quantities of Blood whoſe Magnitudes are equal, that is, if L=l, and K=k: Then, $D.\, d :: P^{\frac{2}{7}}.\, p^{\frac{2}{7}}$, and $V.\, v :: P^{\frac{1}{7}}.\, p^{\frac{1}{7}}$, and $F.\, f :: P^{\frac{4}{7}}.\, p^{\frac{4}{7}}$.

Examples.

Exam. 1. If from ſome Cauſe the Pulſe of the ſame Body becomes twice as quick, as it is in the Morning when the Body is ſitting, and its Heart is free from the Influences

of all disturbing Causes; and if it becomes greater than under those Circumstances, from the Heart's throwing out its usual Magnitude of Blood in half the Time; that is, if P. p :: 2. 1; and K=k: Then, by the second *Corollary* of this *Proposition*, D and d will be as the Numbers 13195 and 10000, V and v as the Numbers 11487 and 10000, and F and f as the Numbers 17411 and 10000. This seems to be the Case of a grown Body heated by an *ardent Fever*, or *violent Exercise*, in which the Pulse is greater than it is ordinarily, and beats about twice as fast as it does in the Morning, when the Body is sitting and its Heart is free from the Influences of all disturbing Causes; and therefore, in a Body so heated, the Diameters of the Blood-Vessels will be increased in the Proportion of 13195 to 10000, the Velocity of the

the Blood in the Proportion of 11487 to 10000, and the Force of the Heart in the Proportion of 17411 to 10000.

Exam. 2. If the Pulſe of the ſame Body be quicker at one Time than at another, in the Proportion of 80 to 70; and if it be greater from the Heart's throwing out its uſual Magnitude of Blood in a leſs Time, that is, if P. p :: 80. 70; and K=k: Then, by the ſecond *Corollary* of this *Propoſition*, D and d will be as the Numbers 10549 and 10000, V and v as the Numbers 10270 and 10000, and F and f as the Numbers 11127 and 10000. The Pulſe is quicker and greater in the *Afternoon*, than it is in the *Morning*; and from many Obſervations, taking one Hour with another of thoſe two Times, it is quicker in grown Bodies one with another, in the Proportion of about 80 to 70: And there-

	Morning.								Afternoon.									
Hours.	8	9	10	11	12	1	2	Mean	3	4	5	6	7	8	9	10	11	Mean
Pulses of A.	65	67	70	73	71	69	70	70	77	77	77	77	76	76	74	74	76	76
Pulses of B.	66	71	72	68	69	67	67	68½	75	81	84	81	79	77	78	78	79	78

therefore, the Diameters of the Blood-Vessels of the same Body will be greater in the Afternoon than in the Morning, taking one Hour with another, in the Proportion of 10549 to 10000; the Velocities in the Vessels will be greater in the Proportion of 10270 to 10000; and the Force of the Heart greater in the Proportion of 11127 to 10000.

I have added this Table, to shew the Tenour of the Pulse at different Hours of the Day; it contains the Numbers of Pulses in a Minute of two healthful Men A and

and B, when ſitting, at the ſeveral Hours from eight a Clock in the Morning to eleven at Night. Theſe Numbers, are Means drawn from a large Number of Obſervations; thoſe of A, from the Obſervations of twelve Weeks; and thoſe of B, from the Obſervations of three Weeks. A eat his Breakfaſt between nine and ten, B his before nine; they both dined together at two, at which Meal B eat more plentifully than A; and they eat little or no Supper.

From this Table it appears, that the Pulſe is ſlower in the Morning, than at any other Time of the Day; that it grows ſomething quicker before Breakfaſt, and a little more ſo after it; that it grows ſlower again before Dinner, and quicker immediately after Dinner; and that the Quickneſs acquired by this Meal, continues for about three or four

Hours,

Hours, and then abates a little; and continues in that State, without any considerable Change, in Bodies which eat and drink little at Night, till they go to Rest.

Exam. 3. If from some Cause the Pulse of the same Body becomes quicker than in the Morning, when the Body is sitting and its Heart is free from the Influences of all disturbing Causes, in the Proportion of 2 to 1; and if it becomes smaller, from the Heart's throwing out in each Systole but a fourth Part of the Blood which it throws out in the Morning under the Circumstances now mentioned, that is, if P. p :: 2. 1; and K. k :: 1. 4: Then, by this *Proposition* and its first *Corollary*, D and d will be as the Numbers 7578 and 10000, V and v as the Numbers 8705 and 10000, and F and f as the Numbers 5743 and 10000. If this be nearly the Case of

of a grown Body in a *malignant Fever*, the *Cold Fit of an Ague*, *Convulſions*, and ſome other Diſeaſes; then, when the Body is ſitting, the Diameters of correſponding Blood-Veſſels will be leſſened in the Proportion of 7578 to 10000, the Velocities in thoſe Veſſels will be leſſened in the Proportion of 8705 to 10000, and the Force of the Heart will be leſſened in the Proportion of 5743 to 10000.

Now ſince in the Caſes mentioned in this *Example*, in which the Force of the Heart is leſſened, the Skin is much paler and colder than in a natural and healthful State; and is extremely pale and cold in *dead Bodies*, in which the Force of the Heart is wholly deſtroyed: And on the contrary, ſince in the Caſes mentioned in the *firſt Example*, in which the Force of the Heart is increaſed, the Skin is much redder

and warmer than in a natural and healthful State: We may from the Colour and Warmth of the Skin, most certainly judge of the Force of the Heart; and at the same time see, how as that Force gradually lessens, the Compass of the Blood's Motion gradually contracts; till at last, that Force wholly ceasing to act, the Motion wholly ceases, even in the largest Vessels nearest to the Heart.

PROPOSITION XVI.

I*F the* Catamenia *flow through* Foramina *in the Sides of the Blood-Vessels of the* Uterus *into its Cavity, if there be the same Number of corresponding* Foramina *in the Sides of corresponding Blood-Vessels in all healthful Bodies; if this Discharge continues*

continues a given Number of Days, and during the Time of its Continuance Bodies be ſituated alike with reſpect to the Horizon; the Quantities of one Diſcharge of grown Bodies will be in Ratios compounded of the duplicate and ſubduplicate Ratios of the Diameters of correſponding Blood-Veſſels, that is, putting C, c *for the Quantities of one Diſcharge of two grown Bodies,* $C.\ c :: D^2\sqrt{D}.\ d^2\sqrt{d}$.

For the whole Quantities of Blood diſcharged by two healthful Bodies in a given Number of Days, will be as the Quantities diſcharged by any two correſponding *Foramina* in that Time; and the Quantities diſcharged by two correſponding *Foramina*, will be as the Squares of their Diameters, and as the Velocities wherewith the Blood flows thro' them, taken together: But the Diameters of two correſpond-

ing *Foramina* are as the Diameters of two correſponding Blood-Veſſels; and the Velocities wherewith the Blood flows thro' the *Foramina*, are as the Velocities wherewith it flows through thoſe Veſſels: And therefore, the Quantities diſcharged by two correſponding *Foramina*, will be as the Squares of the Diameters of two correſponding Blood-Veſſels, and as the Blood's Velocities in thoſe Veſſels taken together, that is, as $D^2 V$ and $d^2 v$; or as $D^2 \surd D$ and $d^2 \surd d$, becauſe $V . v :: \surd D . \surd d$, by *Prop.* 12. But the whole Quantities of one Diſcharge of two healthful Bodies ſituated alike with reſpect to the Horizon, are as the Quantities diſcharged by two correſponding *Foramina*: And therefore $C . c :: D^2 \surd D , d^2 \surd d$.

Cor. 1. If this Propoſition be true, it is evident that this Diſcharge, which

which uſually begins in theſe Countries between the Ages of 14 and 16, will continually increaſe from its firſt Appearance till the Bodies arrive at their full Growth; for both the *Foramina* grow larger, and the Velocity of the Blood increaſes, while Bodies are growing: And it will likewiſe increaſe, from ſome of the *Foramina* being naturally ſmaller than others, on which Account they will neceſſarily, not all at once, but ſucceſſively, become large enough to let the Blood paſs through them.

Cor. 2. If this *Propoſition* be true, this Diſcharge will begin ſooneſt and be greateſt in Bodies which have the largeſt Blood-Veſſels: For it will begin when the *Foramina* are grown large enough to let the red Parts of the Blood (which are its largeſt Parts) paſs thro' them; but they will be ſooneſt large enough to

to do this, in Bodies which have the largest Blood-Vessels: And the Quantities of a Discharge will be greatest, because the *Foramina* are largest, and the Velocity of the Blood is greatest, in such Bodies.

Cor. 3. The Quantities of this Discharge in grown well-proportioned Bodies of different Lengths, and its mean Quantities in all grown Bodies of different Lengths taking those of each Length one with another, will, if this *Proposition* be true, be in Ratios compounded of the simple and the subquadruplicate Ratios of the Lengths of the Bodies; the Diameters of corresponding Blood-Vessels in these Cases, being in the subduplicate Ratios of those Lengths, by *Cor*. 4. *Prop*. 12.

Cor. 4. Hence it appears, that this Discharge will be increased by all

all Things which ſwell the Blood-Veſſels; and on the contrary, leſſened by all Things which contract them: And therefore, it will be increaſed by whatever increaſes the Power of the Heart, and heats the Blood; and leſſened by whatever leſſens the Power of the Heart, and cools the Blood; for the Blood-Veſſels ſwell or contract, as the Force of the Heart is increaſed or leſſened by Heat or Cold, or other Cauſes.

Cor. 5. Hence it appears, that a Diſcharge muſt continue till the Blood-Veſſels and *Foramina* are ſo far contracted by the Loſs of Blood, that the *Foramina* are become too ſmall to let the red Parts of the Blood paſs thro' them; and then it will ceaſe for that Time, and not return again till the loſt Blood be regained, and the Blood-Veſſels and *Foramina*

Foramina be enlarged to the Dimensions they were of at the coming on of the preceding Discharge; and then another Discharge will begin, continue the same Time, and go off as that did. Thus this Discharge happens once a Month, in which Time the lost Blood is regained; continues in these Countries till about the Age of 50; and then wholly ceases, from the *Foramina* becoming too small to let the Blood pass thro' them. The *Foramina* become too small to let the Blood pass thro' them, from a Rigidity in the Blood-Vessels, which hinders them from being dilated by the Blood as usually: For it appears both from Anatomy and common Experience, that the Blood-Vessels and other solid Parts become more rigid, as Bodies advance in Years.

PRO-

PROPOSITION XVII.

IF Q denotes the Quantity of Blood contained in a healthful Body before a Discharge of the Catamenia *begins, and* P *and* p *the Numbers of Pulses in a Minute a little before and after the Discharge, when the Body is sitting, and its Heart is free from the Influences of all disturbing Causes;* C, *the Quantity of the Discharge, will be* $Q \times \frac{\overline{P^4 - p^4}}{P^4}$.

For the Heart being supposed to be free from the Influences of all disturbing Causes before the Discharge and after it, the Heat and Density of the Blood will be the same before and after; and there-

fore, if q denotes the Quantity of Blood contained in the Body after the Discharge is over, $V.v :: Q^{\frac{1}{4}}.q^{\frac{1}{4}}$, by *Cor.* 3. *Prop.* 12; and $V.v :: P.p$, by *Cor.* 2. *Prop.* 14; and from these two Analogies, $Q^{\frac{1}{4}}.q^{\frac{1}{4}} :: P.p$; and $Q-q.Q :: P^4-p^4.P^4$: But $Q-q=C$; and consequently, $C.Q :: P^4-p^4.P^4$; and $C=\frac{Q\times\overline{P^4-p^4}}{P^4}$.

For *Example*, If the Quantity of Blood contained in the Body at the Beginning of the Discharge be 11 *Averdupois* Pounds, and the Pulses in a Minute before and after the Discharge, when the Body is sitting and its Heart is perfectly free from the Influences of all disturbing Causes, be 74 and 73; the Quantity of the Discharge will be above 9 Ounces: If the Quantity of Blood be 11 Pounds, and the Pulses in a Minute

nute before and after be 74 and 72; the Quantity of the Difcharge will be above 18 Ounces.

I have found from Obfervation, that the Pulfe is quicker before the Difcharge than after it. The Pulfe of a well-proportioned Body 64 Inches high, in which this Difcharge was very fmall, was obferved at every Hour of the Day for 8 Months together; and the Pulfe of another Body fix Inches fhorter, in which this Difcharge was very great, was obferved at every Hour of the Day for a Month; and the mean Numbers of Pulfes in a Minute, taken from all the Obfervations made on the two Bodies in the Week before and Week after the Difcharge, were 74 and 72 in the taller Body, and $79\frac{1}{2}$ and 75 in the fhorter. The Differences of thefe Numbers before and after the Difcharge, are too great for the Quan-

tity of the Discharge in these Climates; which I believe does not ordinarily exceed 12 Ounces in tall and well-proportioned Bodies. And if from more Observations of the Pulse of perfectly healthful Bodies, which have this Discharge in due Quantities, it shall be found, that the Differences of its Numbers before and after the Discharge make it greater than it really is in these Climates; then the Quantity of a Discharge cannot be determined by this *Proposition*, which supposes the Heart before and after the Discharge to be free from the Influences of all disturbing Causes: But it may be determined by the next *Proposition*, when from Experiments and Observations all the Terms used in it shall be known.

Proposition XVIII.

If Q *denotes the Quantity of Blood contained in the Body at the Beginning of a Discharge of the* Catamenia, P *and* p *the Numbers of Pulses in a Minute when the Body is sitting,* K *and* k *the Magnitudes of the Quantities of Blood thrown out of the Heart in one Systole, and* Δ *and* δ *the Densities of the Blood, just before the Discharge begins and after it is over;* C, *the Quantity of the Discharge, will be*

$$Q \times \frac{\overline{\overline{KP}^{\frac{4}{3}} \times \Delta - \overline{kp}^{\frac{4}{3}} \times \delta}}{\overline{KP}^{\frac{4}{3}} \times \Delta}.$$

For the Capacities of one and the same Blood-Vessel before and after the Discharge, are as the Squares of its Diameters; which Squares

Squares, when the Body is ſitting, are as $\overline{KP}^{\frac{4}{7}}$ and $\overline{kp}^{\frac{4}{7}}$ by the 15*th Propoſition*: And the Quantities of Blood contained in one and the ſame Blood-Veſſel at thoſe Times are as the Squares of its Diameters and as the Denſities of the Blood taken together: But the Quantities of Blood contained in the whole Body, are as the Quantities contained in one and the ſame Blood-Veſſel when the Body is ſitting: And therefore, the Quantities of Blood contained in the whole Body before and after the Diſcharge, are as $\overline{KP}^{\frac{4}{7}}\times\Delta$ and $\overline{kp}^{\frac{4}{7}}\times\delta$, that is, $Q.\ q :: \overline{KP}^{\frac{4}{7}}\times\Delta.\ \overline{kp}^{\frac{4}{7}}\times\delta$; whence $Q-q=C=$

$$Q\times\frac{\overline{\overline{KP}^{\frac{4}{7}}\times\Delta-\overline{kp}^{\frac{4}{7}}\times\delta}}{\overline{KP}^{\frac{4}{7}}\times\Delta}.$$

Cor. 1. If the Degrees of Heat in the Blood, and conſequently its Denſities,

Denſities, before and after the Diſcharge, be equal; and if the Magnitudes of the Quantities thrown out in one Syſtole before and after be likewiſe equal, that is, if $\Delta = \delta$, and $K = k$; then will $C = Q \times \frac{\overline{P^{\frac{4}{5}} - p^{\frac{4}{5}}}}{P^{\frac{4}{5}}}$.

For *Example*, If the Quantity of Blood contained in the Body when the Diſcharge begins be 11 Pounds, and the Numbers of Pulſes in a Minute before and after the Diſcharge when the Body is ſitting be 74 and 70; the Quantity of the Diſcharge will be above $7\frac{1}{2}$ Ounces; and near 9 Ounces, if the Quantity of Blood in the Body when the Diſcharge begins be 12 Pounds. The Degrees of Heat in the Blood before and after the Diſcharge, may be known by a Thermometer truly adjuſted: And by the Fulneſs of the Pulſe we may judge of the Magnitudes of the

the Quantities of Blood thrown out in one Syſtole: And therefore, from Experiments and Obſervations carefully made by Perſons who have an Opportunity of doing it, the Quantity of a Diſcharge may be nearly known by this *Propoſition.*

Proposition XIX. Problem II.

THE Blood-Veſſels of a particular Part of the Body being obſtructed or opened, contracted or dilated; to determine the Changes made in the Velocities of the Blood, and in the Magnitudes of the Blood-Veſſels, of all the other Parts.

Caſe I. If the Arterial Trunk of a Part be obſtructed or contracted, ſo as either wholly or in ſome Degree to hinder the Blood from flowing

ing thro' that Part; the Velocity will be increaſed in all the other Parts, and its Increaſe will be greater or leſs, *cæteris paribus*, as the Arterial Trunks of thoſe Parts are nearer to or farther from the Trunk which is obſtructed or contracted, by *Cor. Prop.* 7.

The Blood-Veſſels of the Part, whoſe Artery is obſtructed or contracted, will contract and grow leſs, from a Deſtruction or Diminution of the Force of the Blood's Motion, which before the Obſtruction or Contraction of the Trunk kept thoſe Veſſels diſtended: And the Blood-Veſſels of all the other Parts will ſwell or grow larger, by the Force of the augmented Motion of the Blood in thoſe Parts; and their Swelling or Enlargement will be greater or leſs, *cæteris paribus*, as they are nearer to or farther from the obſtructed or contracted Trunk.

Like Changes will be made in the Velocities of the Blood and in the Magnitudes of the Blood-Veſſels of all the other Parts, if, inſtead of the Arterial Trunk of a Part, any of the Branches of that Part (whether Arteries or Veins) be obſtructed or contracted; becauſe ſuch Obſtruction or Contraction will leſſen the Velocity in the Arterial Trunk, by *Cor.* 2. *Prop.* 5; and by Conſequence, will produce like Changes in the Velocities and Magnitudes of the Veſſels of the other Parts, as would be produced by a real Contraction of that Trunk.

Caſe II. If the Arterial Trunk of a Part be opened or dilated, the Blood will flow faſter into that Trunk and ſlower through all the other Parts of the Body than it did before; and the Diminution of Velocity in the other Parts will be

greater

greater or leſs, *cæteris paribus*, as they are nearer to or farther from the Trunk which is opened or dilated, by *Cor. Prop. 7.*

If the Trunk be opened, and the greateſt part of the Blood, which flows into it, flow out of the Orifice; the Veſſels of that Part will contract and grow leſs, from the Blood running out of them, and their not receiving their uſual Supply to keep them diſtended. And the Veſſels of all the other Parts will likewiſe be contracted, from a Diminution of the Velocity of the Blood in them; and their Contraction will be greater or leſs, *cæteris paribus*, as they are nearer to or farther from the Trunk which is opened; and they will undergo like Changes of Magnitude, when the Arterial Trunk is only dilated; tho' the Veſſels of the Part ſupply'd by the dilated Trunk will all ſwell and grow

larger, contrary to what happened to them when the Trunk was opened. Like Changes will be made in the Velocities of the Blood, and in the Magnitndes of the Veſſels of other Parts, when inſtead of the Arterial Trunk, one or more of the Branches (whether Veins or Arteries) of a Part are opened or dilated. For a Dilatation or Opening of any of the Branches will increaſe the Velocity in the Arterial Trunk, by *Cor.* 1. *Prop.* 5; and by Conſequence, will produce like Changes in the Velocities of the Blood, and the Magnitudes of the Veſſels of the other Parts as would be produced by a real Dilatation or Opening of the Arterial Trunk.

Caſe III. If the Venal Trunk of a Part be obſtructed or contracted, the Blood will thereby be either totally or in ſome Degree hindered from

from flowing out of the Part; on which Account, more Blood will flow in for some little Time than flows out; and by Consequence the Vessels will swell till they can be no farther distended. After that, if less Blood flows into the Arterial Trunk of the Part than did before, like Changes of Velocity and Magnitude will be produced in the Blood-Vessels of all the other Parts, as were produced in them by the Obstruction or Contraction of the Arterial Trunk by the *first Case*.

Case IV. If the Venal Trunk of a Part be opened or dilated, the Blood will flow faster thro' the Part than it did before; because the Aperture or Dilatation either takes off or lessens the Resistance arising from the Blood which lies before it: The Velocity therefore will be increased in the Arterial Trunk, and lessened in

in the Veſſels of all the other Parts; and its Diminution in thoſe Veſſels, and the Contraction of their Magnitudes conſequent thereon, will be greater or leſs, *cæteris paribus*, as the Veſſels are nearer to or farther from the Part whoſe Vein is opened or dilated, by the *ſecond Caſe*. The Veſſels of the Part, whoſe Venal Trunk is opened, will contract, notwithſtanding the Velocity of the Blood in them is increaſed: For by the Aperture, the Reſiſtance given by the Blood lying beyond it to the Motion of the Blood through the Part, will be taken off; and by Conſequence, the Velocity of the Blood flowing through the Part will be increaſed: But this Increaſe of Velocity beginning in the Vein at the Place of Aperture, and thence ſucceſſively running through the Venal and Arterial Branches, and at laſt ending in the Arterial Trunk,

Trunk, it is evident, that more Blood will in a given Time flow out of each of theſe Veſſels, that flows in; and by Conſequence, all theſe Veſſels will be contracted; and the Contraction will firſt begin, where the Increaſe of Velocity firſt began, and ſucceſſively go through the Veſſels in the ſame Manner as that did.

Cor. 1. Hence it appears, that if a Part be overloaded with Blood, it will be ſooneſt emptied by opening the Veſſels of the Part it ſelf; and next, by opening the Veſſels of the Parts which are neareſt to it.

Cor. 2. If the Blood flows too faſt into ſome one Part, from an Aperture or Dilatation of ſome of its Blood-Veſſels; the preternatural Influx of Blood into that Part will be leſſened by increaſing the Motion

tion of the Blood thro' the other Parts.

Cor. 3. If the Blood flows too slow into some one Part, from an Obstruction or Contraction of some of its Blood-Vessels; the Motion through this Part will be increased by contracting the Vessels and lessening the Motion thro' the other Parts.

N. B. There may perhaps be some little Disturbances given to these Laws of Apertures and Obstructions, Dilatations and Contractions of the Blood-Vessels, from several Inosculations of Arteries with Arteries, and Veins with Veins; but as these Disturbances cannot be accurately determined, so neither can they be considerable; as appears from the Success of Practice grounded on these Laws.

PRO-

PROPOSITION XX. Problem III.

TO determine the Changes made in the Velocities of the Blood and Magnitudes of the Blood-Veſſels in different Parts of the Body, when it is ſituated differently with reſpect to the Horizon.

The correſponding Arteries and Veins are every where contiguous; and the Veins are larger than their correſponding Arteries, and conſequently, contain a greater Quantity of Blood: On which Accounts, when the Force of Gravity in a Vein conſpires with or oppoſes the Motion of the Blood through it, that Motion will be more increaſed or leſſened by the Force of Gravity in the Vein, than it is leſſened or increaſed

 creaſed

creaſed by the ſame Force in the correſponding Artery; and more or leſs Blood will by virtue of this Force flow through the Vein, than will flow through the Artery in the ſame Time; and therefore, if the Vein and Artery be the two Trunks of a Part; more or leſs Blood will flow out of the Part than flows in, and, in Conſequence thereof, the Blood-Veſſels of the Part will be contracted or dilated. For Inſtance, in the Day when the Body is erect, Gravity conſpires with the Motion of the Blood from the Head, and oppoſes its Motion from the Legs; and in the Night, when the Body is horizontal, Gravity neither conſpires with or oppoſes the Motion from theſe Parts: And hence the Head will contain leſs, and the Legs more Blood, in the Day than in the Night.

PRO-

PROPOSITION XXI. Problem IV.

To determine the Influence and Power of the Soul over the Motion of the Heart.

That the Soul has a very great Power over the Heart, appears from the following Inſtances. A dying Man, who had had little or no Pulſe, and had been in cold clammy Sweats for ſeveral Hours, was by an Accident exceedingly alarmed, and thrown into the greateſt Diſturbance of Mind; upon which his Heart and Blood gradually recovered their Motions to a conſiderable Degree, and kept them above an Hour, till his Mind grew calm and eaſy; and then they loſt them again, and he died in leſs than half

an Hour. A ſtrong Extenſion of the Legs and Arms by the Power of the Will, has quickened the Pulſe 20 Beats in a Minute, and at the ſame Time made it ſo low, that it could ſcarcely be felt. The Pulſes in a Minute of a Man lying, ſitting, ſtanding, walking at the Rate of two Miles in an Hour, at the Rate of four Miles in an Hour, and running as faſt as he could, were 64, 68, 78, 100, 140, and 150 or more. When a Body ſtands up, the Pulſe begins to grow quicker the very Inſtant the Body begins to riſe, or the Soul begins to exerciſe the Power which raiſes it; and when a Body moves, it grows ſtill quicker; and the Soul exerciſes more Force to move the Body, in Proportion to the Quickneſs of the Motion: When a Body firſt ſtands up and begins to move, the Pulſe is ſmaller than it was before; but grows

greater

greater by Degrees, as the Body grows warm by the Motion. A Fit of Laughter has quickened the Pulſe 25 Beats in a Minute: And breathing voluntarily three or four Times faſter than uſually, has quickened it 13 or 14 Beats: The Pulſe is quickened by coughing, ſwallowing, reading loud, or by any Motion that is performed by the Power of the Soul. From hence it appears, that the Motion of the Heart is changed mediately or immediately, by every Change made in the Affections, Activity or Power of the Soul.

Of

Of Respiration.

Proposition XXII.

IF an heated Body be placed in a Wind blowing uniformly; the Time of its cooling will be greater or less, as the Quantity of Matter in the Body, or its Degree of Heat at the Time of its being first placed in the Wind, or the Degree of Heat in the Wind, is greater or less; or as the Surface of the Body is less or greater.

For if the Degree of Heat in the Body at the Time of its being first placed in the Wind, and the Degree of Heat in the Wind, be both given; the Time of its cooling will be

be as the Quantity of Heat in the Body in Proportion to the Measure according to which it is cooled: But the Degree of Heat in the Body being given, its Quantity of Heat will be as its Quantity of Matter; and the Surface of the Body is the Measure according to which it is cooled: And therefore, the Time of cooling will be as the Quantity of Matter in the Body in Proportion to its Surface; and by Consequence, will be greater or less, as the Quantity of Matter is greater or less, or as the Surface is less or greater: If the Body, and Degree of Heat in the Wind, be both given; the Time of its cooling will be greater or less, as the Degree of Heat in the Body, when first placed in the Wind, is greater or less. From Sir *Isaac Newton*'s *Scale of the Degrees of Heat*, it appears, that the Time of the Body's cooling will not be

pro-

proportional to its Heat when first placed in the Wind: For if one and the ſame Body has different Degrees of Heat, the Times of its cooling will be in Arithmetick Proportion, when the Degrees of Heat are in Geometrick Progreſſion; whence the Time of cooling in Proportion to the Heat, will for the moſt part be greater when the Heat is leſs; and therefore, the Time of cooling will not be proportional to the Degree of Heat in the Body when firſt placed in the Wind; and yet it will ever be greater when the Heat is greater, and leſs when it is leſs: If the Body, and its Degree of Heat when firſt placed in the Wind, be both given; the Time of cooling will be greater or leſs, as the Wind is warmer or colder, that is, as the Degree of Heat in the Wind is leſs or greater: And therefore, the *Propoſition* is true.

Cor.

Cor. 1. If a Body of a given Figure be heated to a given Degree, and then placed in a Wind blowing uniformly, and the Degree of Heat in the Wind be given; the Time of its cooling, will be as a given Side and Denſity of the Body taken together, as is evident from the Proof of this *Propoſition.* If the Body be a Cube, the Time of its cooling will be as the Side and Denſity of the Cube; and if a Globe, as the Diameter and Denſity of the Globe; taken together.

Cor. 2. If a homogeneal Body of a given Figure be heated to a given Degree, and then placed in a Wind blowing uniformly whoſe Heat is given; the Time of its cooling will be as a given Side of the Body. If the Body be a Cube, the Time of its cooling will be as the Side of the Cube; and if a Globe, as its Diameter.

Proposition XXIII.

If an heated Body be placed in a Wind blowing uniformly; the Heat which it loses in a very short given Time, when first placed in the Wind will be as the Heat and Surface of the Body taken together directly, and as the Heat of the Air inversly. If S *denotes the Surface of the Body,* H *its Degree of Heat when placed in the Wind,* A *the Degree of Heat in the Wind, and* h *the Heat that is communicated to the Air and lost in the Body in a very short given Time; then* h *will be as* $\frac{SH}{A}$.

For the Air heated by the Body will be constantly carried off by the Wind, and other Air will succeed into

into its Place with an uniform Motion; by which Means, equal Parts of Air will be heated by the heated Body in equal Times, and conceive a Heat proportional to the Heat of the Body; and consequently, one and the same heated Body, placed in a Wind blowing uniformly whose Degree of Heat is given, will when first placed in the Wind communicate to the Air, and consequently lose, in a short given Time, a Heat which is proportional to the Heat of the Body: If the Body be different, but its Degree of Heat, and the Degree of Heat in the Wind, be both given; the Body will communicate to the Air, and consequently lose, in a very short given Time, a Heat which is proportional to the Surface of the Body: And if both the Body and its Degree of Heat be given; it will communicate to the Air, and consequently lose, in a

very ſhort given Time, a Heat which is proportional to the Coldneſs of the Wind; which Coldneſs is inverſly as its Degree of Heat: And therefore, the Heat communicated to the Air, and loſt by a Body heated and placed in a Wind blowing uniformly, will be as the Heat and Surface of the Body taken together directly; and as the Heat of the Wind inverſly, that is, h will be as $\frac{SH}{A}$.

Cor. 1. If the Heat of the Wind be given; the Heat which is communicated to the Air, and loſt in the Body, in a given Time, will be as the Surface of the Body, and as its Degree of Heat when firſt expoſed to the Wind, taken together. If A be given, h will be as SH.

Cor. 2. If the Degree of Heat in the Body, when firſt expoſed to the Wind,

Wind, be given; the Heat communicated to the Air, and loſt in the Body, in a given Time, will be as the Surface of the Body directly, and as the Degree of Heat in the Wind inverſly. If H be given, h will be as $\frac{S}{A}$.

Cor. 3. If the Surface of the Body be given; the Heat which is communicated to the Air, and loſt in the Body, in a given Time, will be as the Heat of the Body, when firſt expoſed to the Wind, directly; and as the Heat of the Wind inverſly. If S be given, h will be as $\frac{H}{A}$.

Cor. 4. If the Degree of Heat in one and the ſame Body, or in different Bodies of which the Surfaces are equal, be given, when firſt expoſed to the Wind; the Heat which the Body or Bodies will communicate

cate to the Air, and consequently lose, in a very short given Time, will be inversly as the Heat, or directly as the Coldness of the Wind.

If S and H be given, h will be as $\frac{1}{A}$.

Proposition XXIV.

THE Life of Animals is preserved by acid Parts of the Air, mixing with the Blood in the Lungs: Which Parts dissolve or attenuate the Blood, and preserve its Heat; and by both these, keep up the Motion of the Heart.

I shall prove the Truth of this *Proposition*, from a Series of Experiments and Observations.

First then, Animals die, when they are deprived of Air by stopping

ping the Wind-pipe, or putting them in an Air Pump and drawing out the Air. And they likewise die soon in a small Quantity of Air so closely confined, as to have no Communication with the rest of the Atmosphere: Small Birds cannot live above three or four Hours in a Quart of such Air; and a Gallon of Air included in a Bladder, and by a Pipe alternately inspired and expired by the Lungs of a Man, will become unfit to preserve Life in little more than one Minute of Time.

Hence it appears, that Air is necessary to preserve the Life of Animals: And likewise, that a constant Supply of fresh Air is necessary to that End.

Secondly, A Candle goes out, glowing Coals and red-hot Iron cease to shine, and Animals die, in the

the Air-Pump on drawing out the Air. A Candle goes out, glowing Coals and red-hot Iron ceaſe to ſhine, and Animals die, in a ſmall Quantity of Air ſo cloſely confined, as to have no Communication with the reſt of the Atmoſphere. Animals die in Air rendered effete by burning Coals or Candles in it till they are extinguiſhed, and glowing Coals or Candles are extinguiſhed in Air rendered effete by Animals breathing in it till they die. *Hook* found, that if Air rendered effete be blown on live Coals, it produces no other Effect, than to blow off the Aſhes and put out the Fire; and that the more you blow, the more dead is the Light, and the ſooner is the Fire quite extinct; inſomuch that in a very little Time, the Coals become perfectly black without emitting the leaſt Glimpſe of Light or Shining: At which Time, if one

Blaſt

Blaſt of freſh Air be blown upon thoſe ſeemingly dead, extinct, and black Coals, they all begin to glow, burn, and ſhine afreſh, as if they had not been at all extinct; and the more freſh Air is blown upon them, the more they ſhine, and the ſooner are they burnt out and conſumed: And Animals put into ſuch effete Air ſoon die, tho' for ſome Time they breath, and move their Lungs as before. The Medium found in Damps, is preſent Death to thoſe who breath it; and in an Inſtant, extinguiſhes the brighteſt Flame, the Shining of glowing Coals, or red-hot Iron, when put into it. Common Air, by paſſing thro' red-hot Braſs, red-hot Iron, red-hot Charcoal, or the Flame of Spirit of Wine, becomes unfit to preſerve Life, and the Shining of Fire and Flame.

Hence it appears, that fresh Air preserves Life in Animals by the very same Power, or by the Operation of the very same Parts, whereby it preserves Fire and Flame in sulphureous and unctuous Substances, when once they are kindled.

Thirdly, If two Parts of compound Spirit of Nitre be poured on one Part of Oil of Cloves or Caraway Seeds, or of any ponderous Oil of Vegetable or Animal Substances, or Oil of Turpentine thickened with a little Balsam of Sulphur; the Liquors grow so very hot in mixing, as presently to send up a burning Flame: If a Drachm of the same compound Spirit be poured upon half a Drachm of Oil of Caraway Seeds, even *in vacuo*, the Mixture immediately makes a Flash like Gunpowder: And well-rectified Spirit of Wine poured on the same

compound Spirit flashes. Common Sulphur and Nitre powdered, mixed together, and kindled, will continue to burn under Water, or *in vacuo*, as well as in the open Air.

Now since Air is necessary to preserve common Fire and Flame in sulphureous and unctuous Substances, when once they are kindled; and it appears by these Experiments, that Fire and Flame may both be produced and preserved in sulphureous and unctuous Substances, by acid Particles even without Air; it follows, that Air preserves Fire and Flame by means of acid Particles: And since it preserves the Life of Animals, by the Operation of the very same Particles whereby it preserves Fire and Flame; it likewise follows, that it preserves the Life of Animals by its acid Particles.

Fourthly, The Venal Blood is of a deep purple Colour, and the Arterial Blood of a bright red, in all Parts of the Body except the Lungs; and in them the Blood is of a dark purple Colour in the Pulmonary Artery, and of a bright red in the Pulmonary Vein. Hence it follows, that the Blood changes its deep purple Colour into a bright red, in the communicant Branches of the Pulmonary Artery and Vein which are ſpread on the Veſicles; and that it changes its bright red into a deep purple Colour, in the communicant Branches of the Arteries and Veins of other Parts. If Blood be drawn out of a Vein, its Surface, which is contiguous to the Air, will acquire the ſame bright red Colour which the Blood acquires in the Lungs; and if this red Surface be cut off with a ſharp Knife, the blackiſh

Surface

Surface of the remaining Blood, being now touched and acted upon by the Air in the same Manner as the first, will acquire the same Colour as that did; and the same Change of Colour will be made in the Bottom of the Cake, if it be turned upwards in the Cup, and exposed to the Air; and if Blood just drawn be stirred and agitated, till the Air be intimately mixed with it throughout, its whole Substance will soon acquire the bright red Colour of Arterial Blood. If the Windpipe be stopped with a Cork, and some Time after the Operation (when the Air which is shut up in the Lungs is made effete, that is, deprived of its acid Parts) Blood be drawn from the Cervical Artery, it will have the same dark purple Colour as Venal Blood.

Now since from these Experiments, the Air must touch Venal Blood

Blood drawn out of the Body to change its deep purple Colour into a bright red, and the acid Parts of the Air cauſe the ſame Change of Colour in the Blood in the Lungs; it will follow, that there muſt be a like Contact of theſe acid Parts with the Blood in the Lungs. And ſince I have ſhewn, that Air preſerves the Life of Animals by its acid Parts; it will likewiſe follow, that the Life of Animals is preſerved by acid Parts of the Air mixing with the Blood in the Lungs.

Fifthly, The bright red Colour acquired by the Blood in the Lungs, from its Purity and Intenſeneſs, is the Red of the ſecond Order of Colours in the Table of Sir *Iſaac Newton's Opticks*, *p.* 206: But the blackiſh or deep purple Colour of Venal Blood turns into this bright Red, without paſſing through the Colours

lours

lours of Blue, Green, Yellow, and Orange; and therefore, must arise from the Indigo and Purple of the third Order, and not from the Indigo and Violet of the second: And consequently by that Table, the tinging Corpuscles of the Blood are lessened in the Lungs.

Hence it appears, that the acid Parts of the Air dissolve or attenuate the Blood in the Lungs.

Oil of Vitriol and Water poured successively into the same Vessel, grow very hot in the mixing. *Aqua fortis*, or Spirit of Vitriol, poured upon Filings of Iron, dissolves the Filings with a great Heat and Ebullition. And the Acid of the Air constantly apply'd to sulphureous and unctuous Substances, when once they are kindled, continues to dissolve them with the Heat of Fire and Flame.

From

From theſe Experiments we learn, that it is the Nature of Acids to diſſolve Bodies with Heat; and therefore, ſince I have ſhewn that the Acid of the Air diſſolves the Blood; it muſt be allowed, that it warms the Blood at the ſame time it diſſolves it.

When Animals are deprived of the Acid of the Air, the Pulſe in leſs than one Minute of Time becomes ſmall and quick; as may be obſerved in a Dog, when his Lungs are made flaccid and without Motion by laying open his Thorax. Upon emptying my Lungs of Air as much as I could, and then ſtopping my Breath; my Pulſe has grown ſmall and quick, with a kind of trembling convulſive Motion, in leſs than half a Minute of Time. And *Thruſton* obſerved the Pulſe to grow ſmaller on an Intermiſſion of Reſpiration,

ſpiration, and greater again on repeating it.

Hence it appears, that the Motion of the Heart leſſens immediately on Animals being deprived of the Acid of the Air; and conſequently, that this Acid by diſſolving or attenuating the Blood and preſerving its Heat, keeps up the Motion of the Heart.

Therefore the *Propoſition* is true.

SCHOLIUM.

1. The Motion of the Lungs in breathing is no otherwiſe neceſſary to the Life of Animals, than as by this Motion the Lungs receive a conſtant Supply of freſh Air.

For *Hook*, after he had laid open the Thorax of a Dog, cut away his Ribs and Diaphragm, and taken off the Pericardium, kept him alive before the *Royal Society* of *London*

above an Hour, by blowing fresh Air into his Lungs with a pair of Bellows. It was observed, that as often as he left off blowing, and suffered the Lungs to subside and lie still, the Dog presently fell into dying convulsive Motions, and soon recovered again on renewing the Blast. After he had done this several Times with like Success, he pricked all the outer Coat of the Lungs with the slender Point of a sharp Penknife, and by a constant Blast made with a double pair of Bellows, he kept the Lungs always distended and without Motion; and it was observed, that while the Lungs were thus kept distended with a constant Supply of fresh Air, the Dog lay still, his Eyes were quick, and his Heart beat regularly; but that upon leaving off blowing, and suffering the Lungs to subside and lie still, the Dog presently fell into dying

ing convulſive Motions, and as ſoon recovered again on renewing the Blaſt, and ſupplying the Lungs with freſh Air.

2. The Motion of the Lungs in breathing does not change the Colour of the Blood in that Part.

For *Lower*, on opening the Pulmonary Vein of a Dog near the left Auricle of the Heart, when his Lungs were kept diſtended and without Motion by a conſtant Supply of freſh Air, obſerved the Blood drawn to have the ſame florid Colour, as the Arterial Blood of other Parts.

Farther, If the Motion of the Lungs changes the Colour of the Blood from a dark Purple to a bright Red; I ſee no Reaſon, why the Motion of the Muſcles when continued for ſome Time ſhould not keep up that red Colour in the Veins; and conſequently, why under ſtrong Exerciſe Venal Blood (contrary to

Experience) ſhould not be of a bright red Colour. For a ſtrong and vigorous Motion of the Muſcles muſt undoubtedly contribute as much to preſerve the bright red Colour of Arterial Blood, as the Motion of the Lungs contributes to produce it.

3. The Death of Animals and Extinction of Flame in a confined Air, are not cauſed by a Diminution of its Elaſticity.

For there is ſometimes as great a Diminution of Elaſticity in the Air in violent Storms of Wind and Hurricanes, as there is in a ſmall Quantity of confined Air at the Time when Animals die and Candles go out in it; and yet no ſuch Effects follow. Farther, If Animals die and Candles go out in a confined Air, from a Diminution of its Elaſtacity; then theſe Effects would not be produced in different Quantities of confined Air, until its Elaſticity

was

was equally diminiſhed in them: But it has been found by Experiments, that at the Time when Animals die and Candles go out in two different Quantities of confined Air, there is a greater Diminution of Elaſticity in the ſmaller Quantity than in the greater: And therefore, Life and Flame are not deſtroyed by a Diminution of the Elaſticity of the Air. This is farther confirmed from an Experiment mentioned above; For if effete Air, however forcibly blown on live Coals, extinguiſhes them in like Manner as it does when in a State of Reſt; then the ſame effete Air, which in a quieſcent State cannot preſerve Life, will not be able to do it when it is preſſed into the Lungs with any Force, even a greater than is ſufficient to ſwell the Air-Veſſels to their uſual Magnitudes: And therefore Animals do not die in a confined Air, from

from the *Vesiculæ* not being sufficiently dilated on account of a Diminution of the Elasticity of the Air. A Diminution of the Elasticity of the Air is no otherwise hurtful, than as it hinders the Vesicles from being sufficiently dilated, and thereby hinders the Blood from receiving its usual Quantity of Acid in a given Time: On which account, the Blood will not be sufficiently dissolved and warmed in the Lungs; which will make Respiration quick and uneasy, but cannot cause sudden Death.

Proposition XXV.

If healthful Bodies be cloathed alike, and placed in a Wind blowing uniformly, or move gently along in a calm and still Air with the same uniform Motion;

Motion; and if Heat be generated in their Blood by the Acid of the Air, as fast as it is lost by being communicated to the Air in their Lungs and at their Skins: The Heats generated in their Blood in a short given Time, will be as the Sums of the internal Surfaces of their Systems of Air-Vessels and external Surfaces of their Bodies, and as the Degrees of Heat in their Blood, taken together, directly; and as the Degrees of Heat in the Wind or calm Air inversly. *If* S, s *denote the Sums of the said Surfaces of two healthful Bodies;* H, h *the Degrees of Heat in their Blood when they are first plac'd in the Wind, or begin to move in a calm and still Air;* A, a *the Degrees of Heat in the Wind or Air; and* G, g *the Heats generated in their Blood by the Acid of the Air in a short given Time: I say, that*

$$G . g :: \frac{SH}{A} . \frac{sh}{a} .$$

For

For ſince the Bodies are ſuppoſed to be cloathed alike, the external Surfaces of their Bodies will be alike expoſed to the Air; and the internal Surfaces of their Syſtems of Air-Veſſels are always alike expoſed to it, on account of Reſpiration; and ſince it is the ſame thing to move gently along in a calm and ſtill Air with an uniform Motion, as to ſtand ſtill in a Wind blowing with the ſame uniform Motion: It is evident, by the 23*d* *Propoſition*, that the Heats communicated to the Air and loſt in the Blood of healthful Bodies in a very ſhort given Time, will be as the Sums of the internal Surfaces of their Syſtems of Air-Veſſels and external Surfaces of their Bodies, and as the Degrees of Heat in their Blood, taken together directly; and the Degrees of Heat in the Wind or Air inverſly: But by Suppoſition, the Heat is generated by the Acid of the

the Air as faſt as it is loſt by being communicated to the Air in the Lungs and at the Skin: And therefore, the Heats generated by the Acid of the Air in the Blood of healthful Bodies in a ſhort given Time, will be as the Sums of the internal Surfaces of their Syſtems of Air-Veſſels and external Surfaces of their Bodies, and the Degrees of Heat in their Blood, taken together, directly; and as the Degrees of Heat in the Wind or Air, inverſly; that is, $G.\, g :: \frac{SH}{A}.\, \frac{sh}{a}.$

Cor. 1. If the Degrees of Heat in the Blood of Bodies under the Circumſtances ſuppoſed in this *Propoſition*, and the Degrees of Heat in the Wind or calm Air be reſpectively equal; the Heats generated in the Blood by the Acid of the Air in a given Time, will be as the Sums

of the internal Surfaces of the Syſtems of Air-Veſſels and external Surfaces of the Bodies. If H=h, and A=a; then will G. g :: S. s.

From ſome Experiments made with a Thermometer at the ſame Time and in the ſame Place, I have found the Heats of the warmeſt Parts of the Skin, and conſequently the Heats of the Blood, to be nearly equal in healthful Bodies of all Ages, notwithſtanding the Limbs of old Bodies are conſiderably colder than the Limbs of young Bodies, or Bodies of a middle Age: And if by a larger Experience, this ſhall be found to be univerſally true; then will this *Corollary* obtain in all healthful Bodies in the ſame Place and at the ſame Time: And as theſe Experiments were made when the Bodies were at Reſt, and the Air ſtill and calm, ſo this *Corollary* will likewiſe

likewiſe obtain nearly in Bodies at Reſt in a calm and ſtill Air, in the ſame Place and at the ſame Time: And granting this, and ſuppoſing the external Surfaces of the Bodies to be proportional to the whole internal Surfaces of their Syſtems of Air-Veſſels, and thoſe whole Surfaces to be proportional to the internal Surfaces of all their Veſicles through which the Acid of the Air paſſes into their Blood; then will the Heats generated in a ſhort given Time in the Blood of healthful Bodies, in the ſame Place and at the ſame Time, be as the internal Surfaces of all the Veſicles of their reſpective Syſtems of Air-Veſſels: And if the Veſicles attract the acid Parts of the Air in Proportion to the Magnitudes of their internal Surfaces, (as I have ſhewn the Blood-Veſſels to act on the Blood by attractive or ſome other Powers, in Proportion

to the Magnitudes of their internal Surfaces) then will the Heats generated in the Blood by the Acid of the Air in a ſhort given Time, be as the attractive Powers of all the Veſicles.

Cor. 2. If the Degrees of Heat in the Blood of Bodies under the Circumſtances ſuppoſed in this *Propoſition*, be equal; the Heats generated in it by the Acid of the Air in a ſhort given Time, will be, as the Sums of the internal Surfaces of the Syſtems of Air-Veſſels and external Surfaces of the Bodies, directly, and as the Degrees of Heat in the Wind or calm Air, inverſly: If $H=h$, then will $G. g :: \frac{S}{A} : \frac{s}{a}$.

If by the *Thermometer* it ſhall be found, that the Degree of Heat in the Blood of healthful Bodies is much

much the ſame at all Seaſons of the Year, and in all Climates; then by this *Corollary*, more or leſs Heat will be generated in the Blood of the ſame Body in a given Time, as the Air is colder or hotter; which cannot be, unleſs the Air when it is cold abounds more with this Acid, than when it is hot: And that it does ſo, appears from Fire burning beſt when the Air is coldeſt, and worſt when it is hotteſt. Now if the Air be cooled by the ſame Acid which generates Heat in the Blood when mixed with it; then as the Air abounds more or leſs with this Acid, it will be colder or hotter; and more or leſs Heat will be both generated and loſt in the Blood, in a given Time.

By the 24*th Propoſition*, the Acid of the Air diſſolves or attenuates the Blood, at the ſame Time it generates Heat in it; and the Diſſolution or Attenuation will be greater

or leſs, as more or leſs of this Acid is mixed with the Blood in a given Time: And therefore the Blood will be more diſſolved or attenuated in Winter than in Summer, in cold Countries than in hot. And if the Want of a ſufficient Diſſolution or Attenuation of the Blood be the Cauſe of *Malignant Diſeaſes*; Bodies will be more ſubject to ſuch Diſeaſes in Summer and hot Countries, than in Winter and cold Countries.

This is the general Law of the Attenuation of the Blood, and Heat generated in it, in a given Time, on Suppoſition that the Degree of Heat in the Blood is given: However, it may ſometimes happen, that the Attenuation of the Blood and the Heat generated in it, may not be proportional to the Degree of Coldneſs in the Air. For the Air may be ſo exceſſively cold, and ſo greatly

ly ſaturated with this Acid, that the mutual Attraction of its Particles, ariſing from their Cloſeneſs to one another, may hinder them from being drawn into the Blood in as great a Quantity, as when the Air abounds leſs with them: And whenever this happens, the Fluidity and Heat of the Blood will be deſtroyed faſter than they are generated; and if this continues for any Time, it muſt of Neceſſity put an End to Life. The Caſe here is much the ſame as in Oil of Vitriol, and ſome other Acids; which from their too great Strength will not diſſolve Metals ſo quickly, nor raiſe ſo great a Heat, as the ſame Acids when made weaker.

Proposition XXVI.

If healthful Bodies, situated alike, whose Hearts and Lungs are free from the Influences of all disturbing Causes, have the mean Capacities of their Systems of Air-Vessels proportional to the mean Capacities of their Systems of Blood-Vessels, and the mean Numbers of their Inspirations in a given Time proportional to the mean Numbers of their Pulses in that Time; the mean Quantities of fresh Air inspired, will be as the mean Quantities of Blood which flow thro' their Lungs in the given Time.

Since by Supposition, the Bodies are situated alike with respect to the Horizon, and their Hearts are free from the Influences of all disturbing Causes; the mean Capacities of the Systems of Blood-Vessels will be as the

the mean Capacities of correſponding Veſſels, that is, as the Squares of their mean Diameters into their Lengths, or into the Lengths of the Bodies; therefore, the mean Capacities of the Syſtems of Blood-Veſſels of Bodies of two different Lengths, will be as $D^2 L$ and $d^2 l$, D and d denoting the mean Diameters of any two correſponding Veſſels, and L and l the Lengths of the Bodies: Since likewiſe by Suppoſition, the mean Capacities of the Syſtems of Air-Veſſels are as the mean Capacities of the Syſtems of Blood-Veſſels; the mean Capacities of the Syſtems of Air-Veſſels of Bodies of two different Lengths, will be as $D^2 L$ and $d^2 l$, when the Bodies are ſitting, and their Hearts free from the Influences of all diſturbing Cauſes: And ſince alſo by Suppoſition, the mean Numbers of Inſpirations are as the mean Numbers of Pulſes

in a given Time; the mean Quantities of fresh Air inspired by healthful Bodies of two different Lengths, will be as the mean Capacities of their Systems of Air-Vessels, and mean Numbers of their Pulses in that Time, taken together, that is, as D^2LP and d^2lp, P and p denoting the mean Numbers of Pulses in the given Time: But by the *first Corollary* of the 14*th Proposition*, $P . p :: \frac{V}{L} . \frac{v}{l}$: And therefore, the Quantities of fresh Air inspired in a given Time will be as D^2V and d^2v, that is, as the mean Quantities of Blood which flow thro' the Lungs in the given Time.

The mean Numbers of Pulses and Inspirations in a Minute, of healthful Bodies of three different Lengths in the Morning when they were sitting, were *65*, *72*, *116*, and *17*, *19*,

19, 30. Hence it appears, that the mean Numbers of Pulſes and Inſpirations in a given Time, are proportional to one another in healthful Bodies, when they are ſituated alike with reſpect to the Horizon, and their Hearts are free from the Influences of all diſturbing Cauſes: And if from Experiments it ſhall be found, that the mean Capacities of the Syſtems of Air-Veſſels are proportional to the mean Capacities of the Syſtems of Blood-Veſſels; then will this *Propoſition* be true in healthful Bodies.

Cor. 1. If this *Propoſition* be true; the mean Quantities of freſh Air inſpired in a given Time by healthful Bodies, will be in Ratios compounded of the duplicate and ſubduplicate Ratios of the mean Diameters of correſponding Blood-Veſſels, that is, as $D^2\surd D$ and $d^2\surd d$.

For $V . v :: \sqrt{D} . \sqrt{d}$, by the *Twelfth Proposition*: But the Quantities of fresh Air inspired in a given Time, are as $D^2 V$ and $d^2 v$, by this *Proposition*: And therefore, the Quantities of fresh Air inspired in a given Time will be as $D^2 \sqrt{D}$ and $d^2 \sqrt{d}$.

Cor. 2. If this *Proposition* be true; the mean Quantities of Air inspired in a given Time by healthful Bodies of different Lengths, will be in Ratios compounded of the simple and subquadruplicate Ratios of the Lengths of the Bodies, that is, as $L \times L^{\frac{1}{4}}$ and $l \times l^{\frac{1}{4}}$. For $D . d :: L^{\frac{1}{2}} . l^{\frac{1}{2}}$, by *Cor.* 4. *Prop.* 12; and by Consequence, $D^2 \sqrt{D} . d^2 \sqrt{d} :: L \times L^{\frac{1}{4}} . l \times l^{\frac{1}{4}}$: But the mean Quantities are as $D^2 \sqrt{D}$ and $d^2 \sqrt{d}$, by the last *Corollary*: And therefore, they will be as $L \times L^{\frac{1}{4}}$ and $l \times l^{\frac{1}{4}}$.

Cor.

Cor. 3. If this *Proposition* be true; the mean Quantities of Air inſpired in a given Time by healthful Bodies of different Lengths, will be in Ratios compounded of the duplicate Ratios of their Lengths, and of the ſimple Ratios of the Numbers of their Pulſes in a given Time, that is, as $L^2 P$ and $l^2 p$. For by this *Propoſition*, the mean Quantities of Air inſpired in a given Time are as $D^2 V$ and $d^2 v$: But by *Cor.* 4. *Prop.* 12, $D^2. d^2 :: L. l$, and by *Cor.* 1. *Prop.* 14, $V. v :: L P. l p$: And therefore, the mean Quantities of Air inſpired in a given Time will be as $L^2 P$ and $l^2 p$.

Cor. 4. If this *Propoſition* be true; the Quantities of freſh Air inſpired in a given Time in Proportion to the whole Quantities of Blood, will be

be as the Numbers of Pulses in a given Time. For $\frac{V}{L} \cdot \frac{v}{l} :: P. p$, by *Cor.* 1. *Prop.* 14: But $\frac{V}{L} \cdot \frac{v}{l} :: \frac{D^2V}{D^2L} \cdot \frac{d^2v}{d^2l}$: And therefore, $\frac{D^2V}{D^2L} \cdot \frac{d^2v}{d^2l} :: P. p.$

SEC-

SECTION III.

Of Digestion and Nutrition, Secretion, and the Discharges of Human Bodies.

Of Digestion and Nutrition.

Proposition XXVII.

THE *Nourishment of Animals changes its Texture in their Bodies, till it becomes like their solid and durable Parts.*

For the solid and durable Parts of Animal Bodies grow out of their Nou-

Nourishment: But their Growth is from an Addition and Adhesion of like Parts: And therefore, the Nourishment of Animals changes its Texture in their Bodies till it becomes like their solid and durable Parts.

Cor. 1. Hence it appears, that Animals will not be rightly nourished, when their Nourishment does not change its Texture in their Bodies till it becomes like their solid and durable Parts.

Cor. 2. Hence it appears, that the Nourishment, by changing its Texture in the Bodies of Animals, becomes more dry and earthy than it was before; otherwise, it would not be like their solid and durable Parts.

PRO-

PROPOSITION XXVIII.

THE Texture of the Nourishment is changed in the Bodies of Animals, by a gentle Heat and Motion.

The first remarkable Change in the Texture of the Nourishment is made in the Stomach: In this Bowel the solid Parts of the Food are dissolved and intimately mixed with the Fluids. This Mixture is usually called *Chyle*.

Some, from observing that Fluids have a Power of dissolving Bodies, have thought that a Fluid in the Stomach dissolves the Food and turns it into Chyle: But as it does not appear from Experiments and Observations, that there is a Fluid in the Stomach endued with such a Power;

 this

this Opinion is without Foundation.

Others, from obſerving the great Strength of the Gizzards of Fowls, and that there is commonly Gravel found in them, have imagined, that the Food is diſſolved in the Stomachs of Fowls, and conſequently in the Stomachs of all Animals, by Attrition or Grinding. But if this Opinion be examined, it will likewiſe appear to be without Foundation. For the Food of Fowls is moſtly Grain, all Sorts of which are hard and covered with tough Skins; and therefore, before this Food can be diſſolved and turned into Chyle, it muſt be ſoftened, and its Skins ground off; the firſt of which is done by Warmth and Moiſture in the Craw, and the ſecond by Attrition in the Gizzard. By theſe Contrivances, the Food of Fowl is prepared and fitted for Di-

geſtion;

geſtion; as human Food is by Cookery and other Ways of preparing it, and by the grinding of the Teeth. But if we ſhould grant, that the Food of Fowl is diſſolved and turned into Chyle by Attrition; it will by no means follow, that Food is ſo diſſolved and turned into Chyle in a human Stomach, which has no Gravel in it, and has but very little Muſcular Strength in Compariſon of the Gizzards of Fowls. There may be many different Contrivances in different Species of Animals, to ſoften, groſly divide, and prepare their Food for Digeſtion; but it will not from thence follow, that their Food is digeſted or turned into Chyle by different Cauſes.

The Food is diſſolved and turned into Chyle by a gentle Heat and Motion. Heat makes many Bodies fluid, which are not fluid in Cold.

Lead is melted by a Heat eight times as great as the external Heat of a human Body; Tin, by a Heat ſix times as great; Wax, by a Heat twice as great; and Bones, with the Addition of a little Water, are diſſolved in a Digeſter by Heat in a little Time. If the Heat of the Stomach be nearly equal to that of the Blood, it may be ſufficient, when the Orifices of the Stomach are pretty exactly cloſed, to diſſolve the Food in a few Hours, and turn it into Chyle; eſpecially when it is aſſiſted by the Motion of the Stomach, which by agitating and mixing the Food will contribute to this End. For ſince Heat can diſſolve ſolid Bodies, and nothing is found in a human Stomach, beſides a gentle Heat and Motion, which can diſſolve the Food and turn it into Chyle; it will follow, that the Food

is digeſted or diſſolved, and turned into Chyle, by a gentle Heat and Motion.

The Chyle in moving through the Inteſtines is farther diſſolved by Heat and Motion: And the fineſt Part of this Fluid being conveyed into the Blood, is ſtill farther changed by the ſame Cauſes, namely a gentle Heat and Motion, till it puts on the Form of Blood, and, at laſt, becomes fit to nouriſh the Body, by being made like its ſolid and durable Parts. The Growth of the Chicken in the Shell out of the White of the Egg, is a ſtrong Proof of the Truth of this: For here is manifeſtly nothing, beſides a gentle Heat and Motion, to change the White of the Egg, ſo as to convert it into Blood, and render it fit Nouriſhment for all the Parts of an Animal Body.

Cor. Hence Animals will not be rightly nouriſhed, when the Texture of their Food is not rightly changed in their Bodies by Heat and Motion; which may be owing, either to an Unfitneſs in the Food for ſuch a Change, or to Degrees of Heat and Motion unfit to effect it.

PROPOSITION XXIX.

THE conſtituent ſolid Parts of Animals, according to their ſeveral Natures, are endued with peculiar attractive Powers of certain Magnitudes or Strengths; by which they draw out of the Fluids moving thro' them like Parts in certain Quantities, and thereby preſerve their Forms and juſt Magnitudes.

For

For without attractive Powers agreeable to their Natures, the constituent ſolid Parts of Animals cannot draw like Particles out of the Fluids moving through them; and conſequently, cannot preſerve their Forms: And unleſs theſe Powers be of certain Strengths, they cannot draw thoſe Parts in ſuch Quantities as are proper to preſerve their Magnitudes: And therefore, the *Propoſition* is true.

Cor. 1. Hence Bodies will not be rightly nouriſhed by proper Food changed by juſt Degrees of Heat and Motion, when the attractive Powers of their ſolid Parts are changed, either in their Natures or in their Magnitudes.

Cor. 2. Hence Animals of the ſame Species will grow faſter or ſlower, out of the ſame Nouriſhment

ment rightly changed by Heat and Motion; as the attractive Powers of their ſolid Parts are ſtronger or weaker. And univerſally, their Growth in a given Time will be greater or leſs; as the attractive Powers of correſponding Parts are greater or leſs; or as the Fluids moving thro' thoſe Parts abound more or leſs with ſimilar Particles, that is, with Particles rightly fitted to be attracted by thoſe Powers.

General SCHOLIUM.

I have ſhewn that the Nouriſhment of Animals becomes more dry and earthy in their Bodies, and that this Change is effected by a gentle Heat and Motion. How a gentle Heat and Motion cauſe this Change in the Nouriſhment, may be underſtood from what Sir *Iſaac Newton* has delivered concerning the Nature of Salt. This great Man, finding

ing from Experiments and Obſervations, that Salts are dry Earth and watry Acid united by Attraction, and that the Earth will not become a Salt without ſo much Acid as makes it diſſolvable in Water, has given the following Account of the Formation of Particles of Salt.

" As Gravity makes the Sea flow " round the denſer and weightier " Parts of the Globe of the Earth, " ſo the Attraction may make the " watry Acid flow round the den- " ſer and compacter Particles of " Earth for compoſing the Par- " ticles of Salt. For otherwiſe the " Acid would not do the Office of " a Medium between the Earth and " common Water, for making Salts " diſſolvable in Water; nor would " *Salt of Tartar* readily draw off " the Acid from diſſolved Metals, " nor Metals the Acid from *Mer-* " *cury*. Now as in the great Globe

" of the Earth and Sea, the denſeſt
" Bodies by their Gravity ſink down
" in Water, and always endeavour
" to go towards the Center of the
" Globe; ſo in Particles of Salt,
" the denſeſt Matter may always
" endeavour to approach the Cen-
" ter of the Particle: So that a Par-
" ticle of Salt may be compared to
" a Chaos; being denſe, hard, dry,
" and earthy in the Center; and
" rare, ſoft, moiſt, and watry in
" the Circumference. And hence
" it ſeems to be that Salts are of a
" laſting Nature, being ſcarce de-
" ſtroy'd, unleſs by drawing away
" their watry Parts by Violence, or
" by letting them ſoak into the
" Pores of the Central Earth by a
" gentle Heat in Putrefaction, until
" the Earth be diſſolved by the Wa-
" ter, and ſeparated into ſmaller
" Particles, which by reaſon of
" their Smallneſs make the rotten

" Com-

"Compound appear of a black "Colour. Hence alſo it may be "that the Parts of Animals and "Vegetables preſerve their ſeveral "Forms, and aſſimilate their Nou-"riſhment; the ſoft and moiſt "Nouriſhment eaſily changing its "Texture by a gentle Heat and "Motion, till it becomes like the "denſe, hard, dry, and durable "Earth in the Center of each Par-"ticle. But when the Nouriſh-"ment grows unfit to be aſſimi-"lated, or the Central Earth grows "too feeble to aſſimilate it, the "Motion ends in Confuſion, Pu-"trefaction and Death." *Newt. Opt. p.* 361, 362.

Hence it appears, that to render the ſaline Part of the Aliment fit to nouriſh the ſolid Parts of Animals and Vegetables, part of the ſuperficial watry Acid muſt by Heat and Motion be drawn off from the Par-

ticles of Salt; by which they will become more denſe, hard, dry and earthy, like the ſolid and durable Parts of the Bodies. And, according to the different Degrees of Heat and Motion in the different Species of Animals and Vegetables, the watry Moiſture will be drawn off in different Proportions, ſo as in each Species to render the Particles like the ſolid Parts of the Bodies of that Species.

And farther, if we conſider that Water is a very fluid taſtleſs Salt, and that Animals and Vegetables, with their ſeveral Parts, grow out of Water and watry Tinctures and Salts; we may from what has been ſaid underſtand the Manner in which the Nouriſhment of Animals and Vegetables is changed by a gentle Heat and Motion, till it becomes like the ſolid and durable Parts of their reſpective Bodies.

Of

Of Secretion.

PROPOSITION XXX.

THE Glands in the Bodies of Animals, according to their ſeveral Natures and Diſpoſitions, are endued with peculiar attractive Powers by which they ſuck in various Juices from the Blood.

That the Glands of Animals have ſuch attractive Powers, I ſhall prove from Experiments and Obſervations.

" If two plane poliſhed Plates of
" Glaſs (ſuppoſe two Pieces of a
" poliſhed Looking-Glaſs) be laid
" together, ſo that their Sides be
" parallel and at a very ſmall Di-
" ſtance from one another, and
" then their lower Edges be dipped
" into

" into Water, the Water will riſe
" up between them. And the leſs
" the Diſtance of the Glaſſes is, the
" greater will be the Height to which
" the Water will riſe. If the Di-
" ſtance be about the hundredth
" part of an Inch, the Water will
" riſe to the Height of about an
" Inch; and if the Diſtance be
" greater or leſs in any Proportion,
" the Height will be reciprocally
" proportional to the Diſtance very
" nearly. The Weight of the
" Water drawn up being the ſame,
" whether the Diſtance between
" the Glaſſes be greater or leſs; the
" Force which raiſes the Water and
" ſuſpends it muſt be likewiſe the
" ſame, and ſuffer no Change by
" changing the Diſtance of the
" Glaſſes. And in like Manner,
" Water aſcends between two Mar-
" bles poliſhed plane, when their
" poliſhed Sides are parallel and at

" a

" a very little Diſtance from one
" another. And if ſlender Pipes
" of Glaſs be dipped at one End
" into ſtagnating Water, the Wa-
" ter will riſe up within the Pipe,
" and the Height to which it riſes
" will be reciprocally proportional
" to the Diameter of the Cavity of
" the Pipe, and will equal the Height
" to which it riſes between two
" Planes of Glaſs, if the Semidia-
" meter of the Cavity of the Pipe
" be equal to the Diſtance between
" the Planes, or thereabouts. And
" theſe Experiments ſucceed after
" the ſame Manner *in vacuo* as in
" the open Air, (as hath been try'd
" before the *Royal Society*,) and
" therefore are not influenced by
" the Weight or Preſſure of the At-
" moſphere." See *Newt. Opt. p.* 366, 367.

Now ſince the Riſe and Suſpenſion of Water between two Glaſs

Planes

Planes and in ſmall Glaſs Pipes, are not owing to the Preſſure of the Atmoſphere; they muſt be cauſed by an attractive Power in the Glaſs, proportional to the Weight of Water ſuſtained by it. Let H, h denote the Heights of the Column of Water ſuſtained between the two Glaſs Planes and of the Cylinder ſuſtained in a ſmall Glaſs Pipe; B, p the Breadth of the Column and Periphery of the Cylinder; and D, d the Thickneſs of the Column and Diameter of the Cylinder: And then the attractive Power which ſuſtains the Column will be as HBD, or as B, becauſe H is as $\frac{1}{D}$; and the attractive Power which ſuſtains the Cylinder, will be as $\frac{hpd}{4}$, or as $\frac{p}{4}$, or as p, becauſe h is as $\frac{1}{d}$.

Hence it appears, that the attractive Power which ſuſtains the Water

Water ariſes only from thoſe Parts of the Glaſs which are contiguous to the Surface of the elevated Water; or more truly, from the Parts of a narrow Surface of the Glaſs, whoſe lower Edge touches the Surface of the Water, and whoſe Height is the ſmall given Diſtance to which the attractive Power, with which Glaſs attracts Water, reaches; and therefore, the attractive Powers of the Glaſs Planes and ſmall Glaſs Pipe will be as 2 B and p. But the Powers are as the Weights ſuſtained by them, that is, $2\,B.\ p :: HBD.\ \frac{hpd}{4}$: Whence HD will be equal to $\frac{hd}{2}$; and, when D is equal to $\frac{d}{2}$, H will be equal to h.

This Power varies in one and the ſame Pipe, or becomes different when exerciſed on different Fluids. For one and the ſame ſmall Glaſs Pipe

will ſuſtain different Weights of different Fluids, as appears from this Table.

Fluids.	Heights in Inches.	Denſities.	Weights.
Oil of Vitriol	1. 1	17245	18969
Water p. 6. Sal Gem p. $\frac{3}{4}$	1. 73	10921	18893
Water p. 6. Sal Gem p. $\frac{1}{2}$	1. 72	10642	18304
Water p. 8. Common Salt p. $\frac{1}{2}$	1. 67	10447	17446
Water p. 6. Salt-petre p. $\frac{1}{3}$	1. 71	10447	17864
Spirit of Vitriol	1. 63	11860	19331
German Spa-Water	1. ·75	10111	17694
Common Water cold	1. 75	10000	17500
Common Water boiling hot	1. 64	9781	16040
Good Blood	1. 64	10400	17056
Serum of good Blood	1. 65	10300	16995
Serum in a Dropſy	1. 65	10171	16782
Urine	1. 60	10270	16432
Saliva	1. 54	10100	15554
Milk of a Cow	1. 42	10279	14596
Gall of an Ox	1. 2	10335	12402
Small Beer	1. 44	10111	14559
Cyder	1. 3	10111	13144
Vinegar	1. 23	10279	12643
Common Ale	1. 2	10300	12360
Red Wine	1. 15	9930	11419
Punch	1. 12	10055	11261
Oil Olive	1. 14	9130	10408
Oil of Turpentine	0. 81	9244	7487
Sal Volatile Oleoſum	0. 84	8774	7370
Brandy	0. 75	9320	6990
Spirit of Wine rectified	0. 73	8324	6076
Spirit of Harts-horn	1. 44	9802	14114

In

In the firſt Column are the Names of the Fluids, in the ſecond the Heights to which they roſe in one and the ſame Glaſs Pipe, in the third the Denſities of the Fluids, and in the fourth the Weights ſuſtained by the ſame Pipe. I obtained the Weights by multiplying the Heights into the Denſities. For the Weights of Cylinders are as their Magnitudes and Denſities taken together, or as their Heights and Denſities taken together if their Baſes be equal: But the Baſes of all the Cylinders of different Fluids ſuſtained by one and the ſame Pipe are equal: And therefore, the Weights of ſuch Cylinders are as their Heights and Denſities taken together.

Hence it appears, that one and the ſame Glaſs Pipe attracts different Fluids with different Degrees of Force. It attracts Spirit of Vitriol more ſtrongly than Oil of Vitriol,

Oil of Vitriol more ſtrongly than Water impregnated with Salt, Water impregnated with Sal Gem and Nitre more ſtrongly than common Water cold, common Water cold more ſtrongly than the Animal Fluids and common Water made boiling hot, the Animal Fluids more ſtrongly than fermented Liquors, fermented Liquors more ſtrongly than Oils, and Oils more ſtrongly than ardent Spirits.

So then, if equal Quantities of all the Fluids of this Table were mixed together, the ſame Glaſs Pipe would ſuck in different Parts of this heterogeneous Fluid in different Proportions. It would ſuck in more Parts of Water impregnated with Salt than of Oil or ardent Spirits. The Parts leaſt attracted would be driven off, to make way for thoſe which are moſt attracted to enter into the Pipe; as in a Fluid

where the Force of Gravity alone takes place, the lighter Bodies are forced to aſcend, to make way for the Deſcent of Bodies which are heavier.

Sir *Iſaac Newton* has proved from Experiments, that the Particles of Light attract ardent Spirits and Oil more ſtrongly than Water: And by Conſequence, if we ſuppoſe a ſmall Pipe to be formed out of Particles whoſe attracting Powers are the ſame with thoſe of the Particles of Light, and one End of it to be dipped into a heterogeneous Fluid compoſed of equal Quantities of all the Fluids of this Table intimately mixed together; ſuch a Pipe would attract the Parts of Oil and ardent Spirits more ſtrongly than thoſe of Water, and ſuck in more Parts of the two former than of the latter. The Fluid therefore drawn out of the heterogeneous Fluid by this

this Pipe, would be different from the Fluid drawn out of it by a ſmall Glaſs Pipe; for two Fluids will be different, when they either conſiſt of different Parts, or of the ſame Parts mixed in different Proportions.

Now ſince Pipes of different Natures draw off different Fluids from one and the ſame heterogeneous Fluid; it follows, that the ſecerning Pipes of the Glands, according to their different Natures and Diſpoſitions, ſuck in various Juices from the Blood, which is a heterogeneous Fluid conſiſting of a great Variety of Parts. And conſequently, the *Propoſition* is true.

PROPOSITION XXXI.

I*F Human Bodies have the ſame Number of correſponding Glands, if*

if those Glands have the same Number of corresponding secerning Pipes arising out of corresponding Blood-Vessels, if the Lengths of corresponding Pipes be as the Lengths of the Bodies, if the Bodies be situated alike with respect to the Horizon, their Hearts be alike free from the Influences of disturbing Causes, and their Blood alike saturated with Parts fit for Secretion; the Quantities of Humour discharged by corresponding Glands in a given Time, will be in Ratios compounded, of the sesquiplicate Ratios of the Diameters of corresponding Blood-Vessels, and of the subduplicate Ratios of the Forces which move the secerned Humours through corresponding secerning Pipes, directly; and of the subduplicate Ratios of the Lengths of the Bodies, inversly. If Z, z *denote the Quantities discharged by two corresponding Glands in a given Time;* F, f *the Forces which move*

move the Humours through two corresponding secerning Pipes; D, d *the Diameters of two corresponding Blood-Vessels; and* L, l *the Lengths of the Bodies; I say, that* $Z . z :: D\sqrt{\frac{DF}{L}} . d\sqrt{\frac{df}{l}}$.

For, allowing the Suppositions made in this *Proposition* to be true, it is evident, that the Quantities of Humour discharged by corresponding Glands in a given Time, will be as the Quantities discharged by any of their corresponding secerning Pipes in that Time: But the Quantities discharged by corresponding secerning Pipes in a given Time, will be as the Squares of their Diameters, and as the Velocities of the Humour flowing through them, taken together; or as the Squares of the Diameters of the Blood-Vessels out of which the Pipes arise, and as the

the Velocities of the Humour flowing through the Pipes, taken together; becauſe the Diameters of the Pipes are as the Diameters of the Blood-Veſſels out of which they ariſe; and the Velocities of the Humour flowing through correſponding Pipes, will by *Prop.* 1, be in Ratios compounded of the direct ſubduplicate Ratios of the Forces which move the Humour through them; and of the inverſe ſubduplicate Ratios, of the Diameters and Lengths of the Pipes, or of the Diameters of correſponding Blood-Veſſels and Lengths of the Bodies: And therefore, the Quantities of Humour diſcharged by correſponding Glands in a given Time, will be in Ratios compounded of the duplicate Ratios of the Diameters of correſponding Blood-Veſſels and of the ſubduplicate Ratios of the Forces which move the Humour thro' cor-

responding secerning Pipes, directly; and of the subduplicate Ratios of the Diameters of corresponding Blood-Vessels and of the Lengths of the Bodies, inversly; that is, $Z.z :: D^2\sqrt{\frac{F}{DL}}. d^2\sqrt{\frac{f}{dl}}$. But $D^2\sqrt{\frac{F}{DL}}. d^2\sqrt{\frac{f}{dl}} :: D\sqrt{\frac{DF}{L}}. d\sqrt{\frac{df}{l}}$: And therefore, $Z.z :: D\sqrt{\frac{DF}{L}}. d\sqrt{\frac{df}{l}}$.

Cor. 1. If this *Proposition* be true, and if the moving Forces of corresponding secerning Pipes be as their Diameters, or as the Diameters of corresponding Blood-Vessels; the Quantities of Humour discharged by corresponding Glands in a given Time, will be in Ratios compounded of the duplicate Ratios of the Diameters of corresponding Blood-Vessels directly, and of the subduplicate Ratios of the Lengths of the Bodies inversly. And the mean Quan-

Quantities of Humour diſcharged in a given Time, will be in the ſubduplicate Ratios of the Lengths of the Bodies. If F. f : : D. d; then will Z. z : : $\frac{D^2}{\surd L}$. $\frac{d^2}{\surd l}$. And ſince by *Cor.* 4. *Prop.* 12. the mean Diameters of correſponding Blood-Veſſels of Bodies of different Lengths, are in the ſubduplicate Ratios of the Lengths of the Bodies; if D, d denote the mean Diameters of correſponding Blood-Veſſels of Bodies of different Lengths, and Z, z the mean Quantities of Humour diſcharged by correſponding Glands in a given Time; then Z. z : : $\surd$L. $\surd$l.

Cor. 2. If this *Propoſition* be true, and if the moving Forces of correſponding ſecerning Pipes be as the internal Surfaces of the Pipes, that is, as their Diameters and Lengths

 taken

taken together, or as the Diameters of correſponding Blood-Veſſels and Lengths of the Bodies taken together; the Quantities diſcharged by correſponding Glands in a given Time, will be in the duplicate Ratios of the Diameters of correſponding Blood-Veſſels. And the mean Quantities diſcharged by correſponding Glands in a given Time will be as the Lengths of the Bodies. If F. f :: D L. d l; then will Z. z :: D^2. d^2. And, ſuppoſing D, d, Z, z to denote mean Diameters of correſponding Blood-Veſſels of Bodies of different Lengths, and mean Quantities of Humour diſcharged by correſponding Glands in a given Time; then Z. z :: L. l.

Cor. 3. If this *Propoſition* be true, and if the moving Forces of correſponding ſecerning Pipes be as the Capacities of the Pipes, or as the

Capa-

Capacities of correſponding Blood-Veſſels; the Quantities of Humour diſcharged by correſponding Glands in a given Time, will be in Ratios compounded of the duplicate and ſubduplicate Ratios of the Diameters of correſponding Blood-Veſſels. And the mean Quantities of Humour diſcharged by correſponding Glands in a given Time, will be in Ratios compounded of the ſimple and ſubquadruplicate Ratios of the Lengths of the Bodies. If F. f :: D^2 L. d^2 l; then will Z. z :: $D^2 \surd D$. $d^2 \surd d$. And ſuppoſing D, d, Z, z to denote mean Diameters of correſponding Blood-Veſſels of Bodies of different Lengths, and mean Quantities of Humour diſcharged by correſponding Glands in a given Time; then, ſince the mean Diameters of correſponding Blood-Veſſels of Bodies of different Lengths are in the ſubduplicate Ratios of the

the Lengths of the Bodies, $Z . z :: L \times L^{\frac{1}{4}} . l \times l^{\frac{1}{4}}$.

Cor. 4. If this *Propoſition* be true, and if the moving Forces of correſponding ſecerning Pipes be as the Capacities of the Pipes, or as the Capacities of correſponding Blood-Veſſels; the Sums of the Quantities diſcharged by all the correſponding Glands, or any given Number of them, in a given Time, will be in Ratios compounded of the duplicate and ſubduplicate Ratios of the Diameters of correſponding Blood-Veſſels: For, ſince the Diſcharges of any two correſponding Glands are in theſe Ratios; the Sum of the Diſcharges of all the Glands, or of any given Number of correſponding Glands, will be in the ſame Ratios. If S, s denote thoſe Sums, then $S . s :: D^2 \surd D . d^2 \surd d$. And if S, s, D, d denote the mean Sums of the Diſcharges

charges in a given Time and mean Diameters of correſponding Blood-Veſſels of Bodies of different Lengths, each Mean being taken from a conſiderable Number of Bodies of the ſame Length; then, ſince the mean Diameters of correſponding Blood-Veſſels are in the ſubduplicate Ratios of the Lengths of the Bodies, $S. s :: L \times L^{\frac{1}{2}}. l \times l^{\frac{1}{2}}$.

Of

Of the Discharges of Human Bodies.

Proposition XXXII.

THE Mean Quantities of Food and Discharges in a natural Day, taken from all the Food and Discharges of a Month, are nearly equal in healthful Bodies.

For I have found by statical Experiments, that tho' the Food and Discharges of healthful Bodies be rarely equal in single Days; yet the mean Quantities in a natural Day, taken from all the Food and Discharges of a Month, are always nearly equal. And therefore, the *Proposition* is true.

10

Cor. 1. If N, n denote the mean Quantities of Food in a natural Day of two healthful Bodies, taken from their whole Quantities of Food in a Month; and P, U, S; p, u, s, the mean Quantities of their Perſpiration, Urine, and Stool, taken from the whole Quantities of thoſe Diſcharges in a Month; then by this *Propoſition*, N is nearly equal to P+U+S, and n nearly equal to p+u+s.

Cor. 2. If a healthful Body at all Seaſons of the Year take daily the ſame Quantity of Food in every Month, taking one Day of the Month with another; the daily Sum of the Diſcharges in every Month, taking one Day of the Month with another, will be likewiſe nearly the ſame at all Seaſons of the Year.

And therefore, if either Perſpiration, Urine, or Stool be greater in ſome Months of the Year than in others; the Sum of the other two will be as much leſs: Otherwiſe the Sum of the three could not be given.

The Truth of theſe two *Corollaries* will farther appear from the following Table.

Months

Months.	Breakfast.	Dinner.	Supper.	Morning.		Afternoon.		Night.		Stool.	Total Urine.	Total Perspiration.	Total Discharges.	Total Food.
				Urine.	Perspiration.	Urine.	Perspiration.	Urine.	Perspiration.					
April.	$23\frac{11}{30}$	44	$16\frac{13}{60}$	$8\frac{23}{60}$	11	$17\frac{33}{58}$	$11\frac{15}{58}$	$16\frac{23}{56}$	$16\frac{3}{56}$	$5\frac{9}{14}$	$41\frac{24}{29}$	$36\frac{13}{15}$	$83\frac{13}{15}$	$83\frac{17}{30}$
May.	$23\frac{3}{10}$	$47\frac{21}{60}$	$21\frac{37}{60}$	$7\frac{11}{60}$	$13\frac{7}{60}$	$17\frac{21}{60}$	$11\frac{37}{60}$	$16\frac{3}{4}$	$19\frac{31}{60}$	$7\frac{5}{12}$	$41\frac{2}{3}$	$44\frac{1}{4}$	$93\frac{1}{3}$	$92\frac{4}{15}$
June.	$27\frac{1}{5}$	$48\frac{2}{15}$	$15\frac{1}{10}$	$7\frac{2}{15}$	$15\frac{41}{60}$	$12\frac{1}{10}$	$12\frac{7}{10}$	$14\frac{8}{15}$	$22\frac{23}{30}$	$5\frac{19}{60}$	$33\frac{23}{30}$	$51\frac{3}{20}$	$90\frac{7}{30}$	$90\frac{13}{30}$
July.	$25\frac{59}{60}$	$41\frac{7}{60}$	$15\frac{8}{15}$	$7\frac{47}{60}$	$14\frac{5}{6}$	$10\frac{3}{10}$	$12\frac{17}{60}$	$12\frac{3}{20}$	$19\frac{19}{60}$	$5\frac{51}{60}$	$30\frac{23}{60}$	$46\frac{13}{30}$	$82\frac{2}{3}$	$82\frac{19}{30}$
August.	$22\frac{1}{6}$	$41\frac{7}{60}$	$20\frac{7}{15}$	$7\frac{19}{26}$	$17\frac{11}{26}$	10	$13\frac{2}{13}$	$12\frac{5}{26}$	$20\frac{9}{13}$	$4\frac{20}{52}$	$29\frac{49}{52}$	$51\frac{7}{26}$	$85\frac{9}{13}$	$85\frac{33}{52}$
Septem^r^.	$18\frac{43}{60}$	48	$19\frac{1}{12}$	$7\frac{1}{2}$	$13\frac{11}{26}$	$13\frac{7}{60}$	$11\frac{1}{60}$	$15\frac{1}{2}$	$19\frac{14}{15}$	$5\frac{3}{20}$	$36\frac{7}{60}$	$44\frac{1}{8}$	$85\frac{2}{30}$	$85\frac{4}{5}$
October.	$18\frac{51}{60}$	$45\frac{53}{60}$	$15\frac{41}{60}$	$7\frac{1}{5}$	$9\frac{59}{60}$	$13\frac{43}{60}$	$10\frac{1}{10}$	$16\frac{41}{60}$	$17\frac{31}{60}$	$4\frac{11}{20}$	$37\frac{3}{5}$	$37\frac{3}{5}$	$79\frac{3}{4}$	$80\frac{5}{12}$
Novem^r^.	$22\frac{5}{13}$	$40\frac{18}{13}$	$15\frac{3}{52}$	$7\frac{17}{26}$	$8\frac{49}{52}$	$12\frac{39}{52}$	$8\frac{9}{13}$	$16\frac{9}{13}$	$18\frac{1}{52}$	$4\frac{37}{52}$	$37\frac{5}{52}$	$35\frac{17}{26}$	$77\frac{6}{13}$	$77\frac{19}{52}$

This

This Table was made from a Courſe of Statical Experiments. The natural Day was divided into three Parts, Morning, Afternoon, and Night; the Morning contain'd ſix Hours from eight to two, the Afternoon ſix Hours from two to eight, and the Night the remaining twelve Hours. I obſerved the Food and the Diſcharges in theſe three Parts of the Day, every Day for eight Months together; and with the Means taken from all the Food and all the Diſcharges in the ſeveral Months, I compoſed the Table: From which it appears,

Firſt, That Perſpiration and Urine vary in their Quantities at different Seaſons of the Year, and that as one encreaſes the other leſſens. In *April* and *May* they were nearly equal, only Urine exceeded Perſpiration a little in *April*, and was exceeded by it a little in *May*. In the

the three Summer Months, *June*, *July*, and *August*, taken one with another, Perſpiration exceeded Urine in the Proportion of about 5 to 3. In *October* and *November* they were nearly equal again, only Urine exceeded Perſpiration a little in *November*. At the End of this Month I was interrupted, and hindered from carrying on the Experiments throughout the whole Year, as I at firſt intended; but I repeated them for about ten Days in cold froſty Weather, and found that Urine then exceeded Perſpiration as much as Perſpiration exceeded Urine in Summer.

Secondly, That Stool is but a ſmall Diſcharge when compared with Perſpiration and Urine, and is but little influenced by the Seaſons of the Year in healthful Bodies. It was a little larger in *May* than in the other Months, from a gentle *Diarrhæa*, for about

about twenty Days in that Month. And it was a little leſs in *October* and *November*, from the Quantity of Food being leſs in thoſe Months than in the others.

Thirdly, That the daily Food and daily Diſcharges taken from all the Food and all the Diſcharges of a Month, are nearly equal at all Seaſons of the Year in healthful Bodies, only the Diſcharges fall a little ſhort of the Food in Autumn, and exceed it a little in the Spring. The Difference between the Food and Diſcharges at theſe Seaſons, ariſes from Perſpiration being more diminiſhed in Autumn by the Cold of the external Air, than Urine is increaſed; and more increaſed in the Spring by the Warmth of the Air, than Urine is diminiſhed. Urine takes up ſome Time at theſe Seaſons to have its Increaſe and Diminution made equal to the Diminution and Increaſe

Increaſe of Perſpiration. And hence it is that Bodies grow heavier in Autumn and lighter in the Spring; and by Conſequence, that they are a little heavier in Winter than they are in Summer. The Change of Weight in Spring and Autumn is not great in healthful Bodies, and probably does not exceed above three or four Pounds; for I have known an Increaſe of five or ſix Pounds to have cauſed a Diſeaſe in the latter End of Autumn: But an Increaſe of four Pounds in two Months is at the Rate of about an Ounce only in a Day: And the ſame Increaſe in three Months is at the Rate of only about two third parts of an Ounce in a Day, taking one Day with another.

A Change is continually made in the Weight of a growing Body; but if we conſider the Quantity and Time of its Growth, we ſhall find

its Food and Diſcharges in a natural Day to be very nearly equal. For if a Child newly born weighs 12 Pounds, and in twenty Years (which I ſhall ſuppoſe to be the Time of growing) come to weigh 168 Pounds; the Food will exceed the Diſcharges in a natural Day, taking one Day of the whole Time of its Growth with another, by ſomething more than the third part of an Ounce. 'Tis true a healthful Child from its feeding plentifully, ſleeping much, and wanting Exerciſe, grows much more the firſt half Year than it does afterwards in the ſame Compaſs of Time; and yet even then there is but little Difference between the Food and Diſcharges in a natural Day, taking one Day with another. For if its Weight when it is born be doubled in the firſt half Year, the Food will exceed the Diſcharges by little more than

than an Ounce in a Day, taking one Day with another. Therefore the Food and Discharges in a natural Day, taking one Day with another, are nearly equal in growing Bodies.

And we may likewise observe a great Change to be frequently made in the Weights of grown Bodies in the Compass of a few Years; but if we consider the Quantity of the Change, and the Time in which it is made; we shall find little Difference between the Food and Discharges in a natural Day, taking one Day of that Time with another. For if a grown Body gain in Weight 50 Pounds in five Years Time, the Food will not exceed the Discharges by half an Ounce in a natural Day, taking one Day of that whole Time with another.

PROPOSITION XXXIII.

SUpposing the same Things as are supposed in the 31st Proposition *and its* 3d Corollary; *and that the Quantities discharged by Stool in a natural Day, taken from the whole Quantities of that Discharge in a Month are in the same Proportion as the daily Discharges of other corresponding Glands taken from their whole Discharges in a Month; the Sum of the Discharges by Perspiration, Urine, and Stool in a natural Day, taken from their whole Quantities in a Month, will in healthful Bodies of different Lengths be in Ratios compounded of the duplicate and subduplicate Ratios of the Diameters of corresponding Blood-Vessels, that is*, $P+U+S.\ p+u+s :: D^2\sqrt{D}.\ d^2\sqrt{d}$.

For

For the Sums of Perſpiration and Urine in a natural Day, taken from their whole Quantities diſcharged in a Month, are in that Proportion by the 4*th Corollary* of the 31*ſt Propoſition:* And the Quantities diſcharged by Stool in a natural Day, taken from the whole Quantities of that Diſcharge in a Month, are by Suppoſition as the daily Diſcharges of other correſponding Glands taken from their whole Diſcharges in a Month: And therefore, the Sums of the three Diſcharges in a natural Day, taken from the wholes of their reſpective Quantities in a Month, will be in the ſame Proportion, that is, $P+U+S.\ p+u+s :: D^2\sqrt{D}.\ d^2\sqrt{d}$.

Cor. 1. If the Diameters of correſponding Blood-Veſſels be in the ſubduplicate Ratios of the Lengths of the Bodies; the Sums of the Quantities of Perſpiration, Urine, and

Stool discharged daily by healthful Bodies of different Lengths, when each Quantity is taken from the whole of that Discharge for a Month, will be in Ratios compounded of the simple and subquadruplicate Ratios of the Lengths of the Bodies. If D. $d :: \sqrt{L}. \sqrt{l}$, then will $P+U+S. p+u+s :: L+L^{\frac{1}{4}}. l+l^{\frac{1}{4}}$.

If this *Proposition* obtains in healthful Bodies; this *Corollary* will also obtain, when the Diameters of corresponding Blood-Vessels are in the subduplicate Ratios of the Lengths of the Bodies. They are in this Proportion in perfectly regular and well-proportioned Bodies, when they are situated alike with respect to the Horizon, and their Hearts are free from the Influences of all disturbing Causes; and the mean Diameters of corresponding Blood-Vessels of all healthful Bodies

dies of different Lengths, when each Mean is taken from the Diameters of thoſe Veſſels in a conſiderable Number of Bodies of each Length, are likewiſe in the ſame Proportion; And therefore, the mean Sums of the Quantities of the Diſcharges in a natural Day of healthful Bodies of different Lengths, when the Quantity of each Diſcharge is taken from its whole Quantity in a Month, will be in Ratios compounded of the ſimple and ſubquadruplicate Ratios of the Lengths of the Bodies: But thoſe Sums of the Diſcharges are equal to the mean Quantities of Food in a natural Day, taken from the whole Quantities of Food in a Month, by *Cor.* 1. *Prop.* 32: And by Conſequence, the mean Quantities of Food in a natural Day of healthful Bodies of two different Lengths, will be in Ratios compounded of the ſimple and

and ſubquadruplicate Ratios of thoſe Lengths. This Proportion obtains nearly in the *Royal* and *Blew-Boys Hoſpital*. For upon inquiring into their Food I found, that taking one Day of the Week, and conſequently one Day of the Month, with another, the Quantities of Food taken daily by Bodies whoſe Lengths are 69 and 54 Inches, are 109 and $85\frac{1}{2}$ *Averdupois* Ounces: But theſe Quantities of Food are nearly in Ratios compounded of the ſimple and ſubquadruplicate Ratios of the Lengths of the Bodies; only the Food of the Boys compared with that of the Men, is greater than in this Proportion by about $5\frac{1}{4}$ Ounces in a Day; which may be owing to the Food of the Boys being ſomething more liquid than the Food of the Men, and to their uſing more Exerciſe. In the Food of the Boys, the liquid part is to the ſolid part a little

little more than 3 to 1; and in that of the Men a little more than $2\frac{1}{2}$ to 1.

Lengths of the Bodies in Inches.	The Lengths into the biquadrate Roots of the Lengths.	Whole Quantities of Food or Discharges in a natural Day in *Averdup*. Ounces.
72	2097	115
69	1988	109
66	1881	$102\frac{3}{5}$
60	1670	$91\frac{1}{2}$
54	1463	80
48	1263	69
42	1069	$58\frac{3}{5}$
36	882	48
30	702	$38\frac{1}{2}$
24	531	29
18	371	20

This Table in its third Column contains the mean Quantities of Food, or mean Quantities of the

Discharges,

Discharges, in a natural Day, of healthful Bodies of the Lengths set down in the first Column. I computed it by the second Column, which contains the Products of the Lengths and biquadrate Roots of the Lengths of the Bodies, taking 109 *Averdupois* Ounces as a proper Quantity of Food for well-proportioned Bodies 69 Inches in Height, on Supposition that the liquid part of the Food to the solid is in the Proportion above-mentioned. The Food of very young Children, as being wholly liquid, should be more than is assigned them by this Table; but what the exact Quantity is I know not for want of Experiments.

Cor. 2. If this *Proposition* be true, as it appears to be by the last *Corollary*; the Sums of the Discharges by Perspiration, Urine, and Stool, in

in a natural Day, taken from their whole Quantities in a Month, will in Bodies of equal Lengths be in Ratios compounded of the ſimple and ſubquadruplicate Ratios of their Quantities of Blood. For the Squares of the Diameters of correſponding Blood-Veſſels are as the Quantities of Blood in Bodies of equal Lengths, that is, $D^2. d^2 :: Q. q$; and the Square-Roots of the ſame Diameters, are as the biquadrate Roots of the Quantities, that is, $\surd D. \surd d :: Q^{\frac{1}{4}}. q^{\frac{1}{4}}$: And therefore, $P+U+S. p+u+s :: Q \times Q^{\frac{1}{4}}. q \times q^{\frac{1}{4}}$.

For Inſtance, if the Quantities of Blood in two healthful Bodies of the ſame Length be as 3 to 2, then $P+U+S. p+u+s :: 19741. 11892$. If the Length of the Bodies be ſix Feet, and the Quantity of Food in a Day of that Body which has the

 greater

greater Quantity of Blood be 116 Ounces; the Quantity of Food in a Day of the other Body will be about 70 Ounces.

Proposition XXXIV. Problem V.

To determine the Proportion of Perſpiration to Urine, at different Seaſons of the Year, at different Times of the natural Day, under different Kinds and Degrees of Exerciſe, in Bodies of different Ages, and Bodies nouriſhed by different Kinds of Food.

I. Perſpiration with reſpect to Urine is greater in Summer than in Winter. It was near three times as great in the Body from which the Table in *p.* 259 was made, and it is generally greater, tho' not in the

the ſame Proportion, in healthful Bodies. A warm Air warms the Skin and increaſes Perſpiration, and a cold Air cools the Skin and leſſens Perſpiration; but as Perſpiration increaſes or leſſens, Urine on the contrary leſſens or increaſes by that Table. The Proportion of Perſpiration to Urine is regulated by the Heat of the Skin; and as far as the Heat of the Skin is increaſed or leſſened by the Heat or Cold of the external Air, the Proportion of Perſpiration to Urine will be increaſed or leſſened by the Heat or Cold of the external Air. Accordingly, I have obſerv'd Perſpiration to have been only equal to, nay ſometimes to have fallen ſhort of, Urine in the Summer-Time, in Bodies which have been little expoſed to the Heat and Cold of the external Air. And as far as I can judge from the Obſervations I have made,

this chiefly happens in Bodies whoſe Skins are naturally cool by a ſpare Diet, or a languid Motion of the Blood, or both.

II. From the Table *p.* 259 it appears, that Urine is always greater in the Afternoon than in the Morning; that Perſpiration during the warm Seaſon is leſs in the Afternoon than in the Morning, and that both are greater in the Day than in the Night. But as the Man from whom that Table was made, walked ſome Hours every Day, and generally more in the Morning than in the Afternoon; we cannot from that Table determine theſe Diſcharges, or their Proportions to one another, at different Times of the Day, in Bodies which are at Reſt. To obtain theſe nearly, I took the Quantities of Perſpiration and Urine diſcharged by two healthful Men B

and

and D, in the ſeveral Hours of the Day for four Days together in very hot Weather, and with the mean Quantities of the Diſcharges in thoſe Hours, compoſed the following Table,

Hours.	B Perſpiration.	B Urine.	D Perſpiration.	D Urine.
6	$1\frac{7}{8}$	$0\frac{15}{19}$	2	1
7	$1\frac{5}{6}$	1	$1\frac{2}{7}$	1
8	2	1	$1\frac{1}{2}$	$1\frac{1}{7}$
9	2	$1\frac{5}{6}$	$1\frac{4}{7}$	$1\frac{3}{10}$
10	2	$1\frac{1}{2}$	$1\frac{9}{10}$	1
11	$1\frac{3}{4}$	1	$1\frac{2}{7}$	1
12	$2\frac{1}{3}$	1	$1\frac{4}{7}$	1
1	$2\frac{2}{3}$	$1\frac{1}{4}$	$1\frac{1}{2}$	1
2	2	1	$1\frac{1}{3}$	1
3	$3\frac{1}{2}$	$1\frac{1}{4}$	2	1
4	$2\frac{1}{3}$	2	$1\frac{1}{2}$	$1\frac{2}{7}$
5	$2\frac{1}{3}$	2	$1\frac{4}{7}$	1
6	$2\frac{2}{3}$	2	2	1
7	2	2	2	1
8	$2\frac{1}{3}$	$2\frac{1}{3}$	2	1
9	$2\frac{2}{3}$	$1\frac{2}{3}$	$1\frac{1}{2}$	$1\frac{1}{2}$
10	$2\frac{1}{3}$	$1\frac{2}{3}$	$1\frac{1}{2}$	$1\frac{1}{2}$

B took

B took 86 Ounces of Food in a Day, and D only 63: They both eat their Breakfast at eight a Clock in the Morning, dined at two, and supped at eight at Night. It is to be observed, that the Numbers corresponding to the Hour 6 in the Morning, are the mean Quantities of Perspiration and Urine which were drawn off from the Blood in every Hour of the Night, taking one Hour with another.

Setting aside Exercise, and supposing the natural Day to be divided into three equal Parts, Morning, Afternoon, and Night, and the Morning to begin at six a Clock; the Quantities perspired by B and D in the Morning, Afternoon, and Night, were nearly by this Table, 16, 20, 15, and 13, 14, 16; and the Quantities of Urine made by these Bodies in the same Times, were nearly 9, 15, $7\frac{1}{2}$, and 8, $8\frac{1}{2}$, 9. The Proporti-

ons

ons of Perſpiration to Urine in theſe Times, were 177, 133, 200, in B; and 162, 164, 177, in D. Hence we learn, that the Proportion of Perſpiration to Urine, is greater in the Night when Bodies are at Reſt than in the Day-time; that there is no great Difference in this Proportion in theſe Times, in Bodies which eat ſparingly and drink but little Wine, which as the Caſe of D; and that in Bodies which eat plentifully and drink Wine, this Proportion is often leſs in the Afternoon than in the Morning, which was the Caſe of B. Wine in moſt Bodies increaſes the Diſcharge by Urine; and as that Diſcharge increaſes, the Proportion of Perſpiration to it will neceſſarily leſſen; unleſs Perſpiration be increaſed in the ſame Proportion as Urine is increaſed, which I believe very ſeldom happens. Hence we may judge of the

Pro-

Proportion of Perſpiration to Urine at different Times of the natural Day, in Bodies which are at Reſt; and at the ſame time ſee, that notwithſtanding the Inequalities of this Proportion in different Parts of the natural Day, the Proportion of Perſpiration to Urine in the whole natural Day, is nearly the ſame at the ſame Seaſon of the Year in healthful Bodies; it was nearly 162 in B, and 168 in D.

III. The Proportion of Perſpiration to Urine, is increaſed by all thoſe Exerciſes which increaſe the Motion of the Blood and warm the Skin. Two Men of nearly the ſame Height and Weight walked a Mile in half an Hour, and in that Time each perſpired about $3\frac{1}{2}$ Ounces, which was about three times as much as they ordinarily perſpired in the ſame Time in the Heat of Summer with-

without Exerciſe. This Degree of Exerciſe gave a glowing Warmth to the Skin; it did not make them ſweat, but would have cauſed a gentle breathing Sweat, had it been continued much longer. The ſame Men walked above two Miles in half an Hour, and in that Time one perſpired nine Ounces, and the other eight, which was about eight times as much as they ordinarily perſpired in the ſame Time in the Heat of Summer without Exerciſe. This Degree of Exerciſe made them ſweat profuſely. A third Man, who was fat and much taller than either of the others, walked two Miles in half an Hour, and in that Time perſpired thirteen Ounces and a half, which was about nine times as much as his Summer's Perſpiration in the ſame Time without Exerciſe. And a Boy ſeven Years old, who without Exerciſe perſpired

half an Ounce in half an Hour in the Heat of Summer, by walking at ſuch a Rate as gave a gentle Warmth to his Skin, but did not make him ſweat, perſpired about three times as much in the ſame Time. At the Beginning of the Exerciſe of Walking I have obſerved, that Urine has been increaſed as well as Perſpiration; but on continuing the Exerciſe, Urine in a very little Time has decreaſed, and grown leſs than it was before the Exerciſe, from the large Diſcharge which was made by the Skin. If we ſuppoſe the Quantity of Urine not to be leſſened by Exerciſe, as it may not in Perſons who by Drink ſupply the Loſs which is made by Perſpiration, then will the Proportion of Perſpiration to Urine be 6 to 1, in Perſons who walk at ſuch a Rate as to give a glowing Warmth to their Skins but not to cauſe Sweat, and 16 to 1

in

in Perſons who walk at ſuch a Rate as to ſweat profuſely, on Suppoſition that the Proportion of Perſpiration to Urine is 2 to 1 in the Heat of Summer. The Exerciſe of Riding increaſes Perſpiration, but neither ſo ſuddenly, or in ſo great a Degree, as the Exerciſe of Walking, as appears from the following Inſtance. A healthful Man upwards of ninety Years of Age, who commonly without Exerciſe diſcharged four or five times as much by Urine as he did by Perſpiration, obſerved that in the Night, after riding ſeveral Hours the Day before, he always perſpired as much as he diſcharged by Urine. In this Caſe therefore, Perſpiration to Urine was increaſed by Riding in the Proportion of 4 or 5 to 1.

IV. The Proportion of Perſpiration to Urine in Bodies of diffe-

rent Ages will be greater or leſs, as the external Heat of the Body is greater or leſs: But the external Heat of the Body is leſs in old Bodies than in others: And therefore, the Proportion of Perſpiration to Urine will be leſs in old Bodies than in others. In the old Man above-mentioned, this Proportion was leſs than in Bodies in the Vigour of their Age in the Heat of Summer, in the Proportion of 1 to 8 or 10.

V. The Proportion of Perſpiration to Urine in Bodies nouriſhed by different Kinds of Meats and Drinks will be greater or leſs, as thoſe Meats and Drinks are fitted to warm or cool the Skin by warming or cooling the Blood, and increaſing or leſſening its Motion. As to Drinks, Water and watry Liquors drunk hot warm the Skin and increaſe

creaſe Perſpiration; and drunk cold cool the Skin, and increaſe Urine. Three or four Quarts of Chalybeate Waters will paſs off by Urine in many Bodies in leſs than three Hours Time. Wine and other fermented Liquors drunk cold and in large Quantities frequently paſs off very quick by Urine, but not altogether ſo quick as cold Water; and drunk hot they increaſe Perſpiration. Water impregnated with Nitre is colder and more diuretick than plain Water. As to Meats, thoſe which are dry and warming increaſe Perſpiration; and thoſe which are moiſt and cooling increaſe Urine. Ripe Apples increaſe Perſpiration, as appears from the following Inſtance. The old Man above-mentioned, whoſe Perſpiration in the eighty-ſixth Year of his Age was not above $\frac{1}{4}$th part of his Urine, by eating three quarters of a Pound of mellow

mellow Apples at Night with Bread, brought his Perſpiration to be nearly equal to his Urine, leſs only in the Proportion of 13 to 16. That this Change in Perſpiration was owing to the Apples, appeared from hence, that on leaving them off, his Perſpiration grew leſs, and returned to what it was before he began to eat them.

From theſe Inſtances it appears, that the Proportion of Perſpiration to Urine, is increaſed or leſſened by Meats and Drinks, as they increaſe or leſſen the Heat and Motion of the Blood.

SEC-

[illegible]

[illegible] Effects of [illegible] Heat [illegible] of different Kinds of [illegible] and of Exercise, on animal [illegible]

PROPOSITION XXXV.

If any animal Force be extended by a Force acting uniformly some [illegible] Length will be directly as that [illegible], and inversely as the Extension [illegible] by it in a given Time: And if [illegible] of a given Sort of Mat- [illegible] and its Extension caused by the [illegible] in a given Time be finally as [illegible] will be very nearly as

the

mellow Apples at Night, which brought his Perspiration to be equal in point to his Urine; his ... the Proportion of ... this Change in Perspiration ... owing to the Apples, appeared ... hence, that on leaving them ... his Perspiration grew less, and ... turned to what it was before he began to eat them.

From these Instances it appears that the Proportion of Perspiration to Urine, is increased or lessened by Meats and Drinks, as they increase or lessen the Heat and Motion of the Blood.

SECTION IV.

Of the Effects of various Fluids, of Age, of different Kinds of Weather, and of Exercise, on animal Fibres.

Proposition XXXV.

If an animal Fibre be extended by a Force acting uniformly upon it, its Strength will be directly as that Force, and inversly as the Extension caused by it in a given Time: And if the Fibre be of a given Sort of Matter, and its Extension caused by the Force in a given Time be small; its Strength then will be very nearly as

the Square of its Diameter directly, and as its Length inversly. If S *denotes the Strength of a Fibre,* F *the extending Force,* E *its Extension caused by the uniform Action of that Force in a given Time,* D *its Diameter, and* L *its Length; then* S *will be as* $\frac{F}{E}$; *and if the Fibre be of a given Sort of Matter, and its Extension be small, then* S *will be very nearly as* $\frac{D^2}{L}$.

For the Strength of a Fibre will be greater, when either a greater Force is required to extend it thro' the same Space, or the same Force is required to extend it thro' a less Space, in a given Time: And therefore its Strength will be as the extending Force directly, and as the Extension caused by the uniform Action of that Force in a given Time

Time inverſly, that is, S will be as $\frac{F}{E}$. And by meaſuring the Diameters and Lengths of Hairs, and taking their Extenſions cauſed by the uniform Action of Forces in a given Time, I found that in ſmall Extenſions the Ratio of the extending Force to the Extenſion cauſed by it in a given Time, is very nearly equal to the Ratio of the Square of the Diameter of a Hair to its Length; that is, $\frac{F}{E}$ is very nearly equal to $\frac{D^2}{L}$. Therefore the *Propoſition* is true.

Cor. If the extending Force be given, the Strength of a Fibre will be inverſly as its Extenſion cauſed by the uniform Action of that Force in a given Time. If F be given, S will be as $\frac{1}{E}$.

I examined the Strengths of different Kinds of Fibres, namely Hairs, Fibres of Silk, and Nerves of Animals; and finding them all to be affected by the same Fluids in like manner but in different Degrees, I chose human Hairs as the fittest for Experiments, and from them composed this Section.

The Hair I used in composing the two following Tables, was that of a healthful young Woman 22 Years of Age. And in order to discover how it was affected by different Fluids, I used such Hairs only whereof equal Lengths were equally extended by the same Force in a given Time, that is, such whereof a Length of 10 Inches was extended by a given Weight through 5 Divisions of a Scale, in which an Inch was divided into 40 equal Parts. And when I had wet one of those Hairs with some Fluid for one Minute,

Tab. 2. p. 291

I examined the S[illegible] dif-
ferent Kinds of Fibres, [illegible]
Hairs, Fibres of Silk, and [illegible]
of Animals, and finding them [illegible]
to be affected by the same Fluid [illegible]
like manner but in different de-
grees, I chose human Hairs [illegible]
[illegible] for Experiments, and [illegible]
[illegible] compiled this Section.

The Hair I used in composing [illegible]
the following Tables, was [illegible]
[illegible] a Human [illegible]
of Age. And in order to dis-[illegible]
how it was affected by [illegible]
Fluids, I used such Hairs [illegible]
of equal Length [illegible]
[illegible] the same [illegible]
[illegible]
Length [illegible]
[illegible] Weight [illegible]
[illegible] which [illegible]
[illegible]
[illegible]
[illegible]

nute, I took its Extension when wet in the Divisions of the same Scale. And having got these two Extensions, and supposing E to express the Extension of the wet Hair; its Degrees of Strength when dry and when wet, will be as $\frac{1}{5}$ and $\frac{1}{E}$, by this *Cor.* or as 1 and $\frac{5}{E}$, or as 100000 and $\frac{500000}{E}$. And therefore the Strength of the dry Hair being expressed by 100000, its Strength when wet with that Fluid, will be express'd by $\frac{500000}{E}$.

I measured the Extensions of the Hairs by means of an *Apparatus* thus contrived. ABCD represented a Ruler, whole Length AD is about two Feet, its Breadth DC about three quarters of an Inch, and its Thickness CV one quarter of an Inch. The upper End is received

ceived into a Block, ſo as that the Ruler hangs perpendicularly to the Plane of the Horizon. IKL is a ſliding Plate of Braſs ſo contrived, as that it may be fixed any where on the Ruler by means of a Screw M preſſing the Plate of Braſs NO againſt the Side BCV. From the Middle of this ſliding Plate projects a ſmall Cylinder repreſented at r, having an Hole drill'd thro' it at right Angles to its Axis and to the Horizon; and the Axis of the Cylinder receives a Screw which preſſes againſt the Center of its Baſis. The lower End of the Ruler is faced with a thin Plate of Ivory ſeven Inches in Length; each Inch is divided into 40 equal Parts, ab, bc, &c. and each of thoſe Parts by means of a diagonal Scale into four others. pRq is a ſmall piece of Braſs 8 Grains in Weight, having a Groove on its upper Part, where it

it is pierced with a very ſmall Hole in order to receive the End of a Hair under the Screw o; and pq repreſents an human Hair for cutting the Diviſions on the Scale PC.

Having paſs'd one End of an Hair thro' the ſmall Hole at R, and faſten'd it by turning the Screw o, I drew the other End by help of a ſmall bearded Wire through the Hole in the Cylinder r, and fixed it by the Screw n, ſo as always to have an Interval of 10 Inches between thoſe Screws. Then on the Groove of the Braſs pRq I hung a Scale with a Weight W, and obſerved the encreaſed Length or Extenſion of the Hair when dry in two Minutes of Time, cauſed by the uniform Action of the given Weight of 300 Grains, which was the Sum of the Weights of the Scale, of W, and of the little Braſs pRq. If this Extenſion either exceeded or fell ſhort of 5 Diviſions of the

the Scale, the Number pitch'd upon for the given Extension of a Hair when dry, I threw this Hair away and try'd others, till I met with one which had exactly that given Extension. I then took off the Scale, and gently rub'd the Hair from End to End with a Feather dipp'd in some Fluid, and continued thus wetting it for one Minute; at the End of which Time, I put on the Scale again, and observed the Extension produc'd in two Minutes, the Hair being kept wet, by gently rubbing it with the wet Feather all the Time. Sometimes I got the given dry Extension by taking a Mean of two or more dry Extensions which were near it, and the wet Extension corresponding to it by taking a Mean of the wet Extensions of the same Hairs. And after I had found the Extension of a Hair wet with Water to be 35, its Extension when dry being

being 5: I frequently did not take the dry Extensions, but took the Extensions of Hairs, first wet with Water, and afterwards, when they were dried, with other Fluids. And if the Extension of a Hair wet with Water, was a few Divisions either above or below 35, I got the true Extension of a Hair wet with some other Fluid corresponding to the Extension 35 when wet with Water, by this Analogy. As the Extension greater or less than 35 is to 35, so is the Extension corresponding to that greater or less Extension when a Hair is wet with some other Fluid, to the Extension it would have had when wet with that Fluid, had its Extension when wet with Water been 35. Thus I got the Extensions of Hairs, and from those Extensions composed the following Tables.

TABLE I.

	Extension when dry.	Extension when wet.	Strength of a Fibre.
Dry	5		100000
Wet with Mutton Suet melted		$5\frac{1}{10}$	98039
Fat of a Turkey melted		$5\frac{1}{8}$	97561
Oil Olive		$5\frac{1}{5}$	96154
Oil of Turpentine		$5\frac{1}{4}$	95238
Oil of Fennel		$5\frac{1}{4}$	95238
Butter melted		$5\frac{1}{4}$	95238
Salt of Tartar *per deliquium*		$6\frac{3}{10}$	79365
A strong Solution of common Salt		$6\frac{3}{4}$	74074
Spirit of Wine rectified		7	71428
Rum		$9\frac{1}{2}$	52631
A strong Solution of Sal-armoniac		$9\frac{1}{2}$	52631
Good Brandy		10	50000
A strong Solution of Sal-gem		$12\frac{1}{2}$	40000
A strong Solution of Nitre		20	25000
A strong Solution of fine Sugar		20	25000
Meath		$22\frac{1}{2}$	22222
Cream of Cow's Milk		$23\frac{3}{10}$	21459
Juice of Mazzard Cherries		$24\frac{2}{3}$	20272
Gravy of roast Beef		26	19231
Cow's Milk skim'd		26	19231
A strong Solution of Green Vitriol		27	18518
Juice of a ripe Nectarin		$27\frac{3}{5}$	18116
Juice of a Lemon		28	17857
Juice of a ripe Peach		$28\frac{1}{2}$	17544
A strong Solution of Alum		$28\frac{1}{2}$	17544
French Claret		29	17241
A strong Solution of Salt of Tartar		$29\frac{1}{2}$	16949
Vinegar		$29\frac{1}{2}$	16949
Juice of common Cherries		$29\frac{1}{2}$	16949
Sheep's Gall		30	16666
Juice of a green Apricock		$30\frac{1}{2}$	16393

Juice

TABLE I.

	Extension when dry.	Extension when wet.	Strength of a Fibre.
Wet with Juice of a ripe Apple	5	$30\frac{1}{2}$	16393
Juice of raw Beef		31	16129
Gravy of roast Veal		31	16129
Boyl'd Water, when cold		31	16129
Gravy of boyl'd Mutton		31	16129
Juice of Rasberries		31	16129
Juice of Billberries		$31\frac{3}{4}$	15748
Juice of Currans		32	15625
Juice of Gooseberries		32	15625
Juice of Parsley		32	15625
Dew in June		$32\frac{1}{2}$	15384
Juice of raw Turneps		$32\frac{7}{10}$	15290
Juice of Sorrel		$32\frac{3}{4}$	15267
Juice of a very ripe Apricock		33	15151
Juice of raw Carrots		33	15151
Juice of Cucumbers		33	15151
Juice of Purslain		33	15151
Juice of Lettice		33	15151
Juice of Mint		33	15151
Juice of Fennel		33	15151
A strong Infusion of Mustard-seed in Water		$33\frac{1}{6}$	15075
Juice of raw Onions		34	14706
Juice of raw Potatoes		34	14706
Juice of raw Cabbage		$34\frac{1}{2}$	14492
Water cold		35	14285
Juice of raw Parsneps		35	14285
Juice of Dandelion		35	14285
Juice of Sage		$35\frac{1}{4}$	14184
Juice of raw Selery		36	13888
Juice of Water Cresses		37	13514
Juice of Scurvy-Grass		38	13158
Spirit of Sal-armoniac		72	6896
Water hot		80	6250
Spirit of Vitriol		87	5747

Table II.

	Extension when dry.	Extension when wet.	Strength of a Fibre from Experiments	Its Streng. according to the Mixture.
Dry	5		100000	
Wet with 2 Parts of Oil-Olive, and 1 part of Sheep's Gall, mix'd		27	18518	69658
2 Parts of good Brandy, and 1 part of Sheep's Gall, mix'd		34	14706	38888
2 Parts of Cream of Cows Milk, and 1 part of Sheep's Gall, mix'd		34	14706	19861
2 Parts of French Claret, and 1 part of Sheep's Gall, mix'd		33	15151	17049
2 Parts of Meath, and 1 part of Sheep's Gall, mix'd		26	19231	20370
2 Parts of a strong Solution of common Salt, and 1 part of Sheep's Gall, mix'd		9.15	54644	54938
2 Parts of Lemmon Juice, and 1 part of Sheep's Gall, mix'd		28	17857	17460
2 Parts of Salt of Tartar *per deliquium*, and 1 part of Sheep's Gall, mix'd		$6\frac{1}{10}$	79365	58465
2 Parts of Oil-Olive, and 1 part of Spirit of Sal-armoniac, mix'd		47	10638	66401
2 Parts of good Brandy, and 1 part of Spirit of Sal-armoniac, mix'd		40	12500	35632

TABLE II.

	Extension when dry.	Extension when wet.	Strength of a Fibre from Experiments	Its Streng. according to the Mixture.
Wet with 2 Parts of Cream of Cow's Milk, and 1 part of Spirit of Sal-armoniac, mix'd	5	46	10870	16605
2 Parts of French Claret, and 1 part of Spirit of Sal-armoniac, mix'd		45	11111	13793
2 Parts of Meath, and 1 part of Spirit of Sal-armoniac, mix'd		$30\frac{1}{2}$	16393	17113
2 Parts of a strong Solution of common Salt, and 1 part of Spirit of Sal-armoniac, mix'd		10	50000	51681
2 Parts of Lemon Juice, and 1 part of Spirit of Sal-armoniac, mix'd		$29\frac{1}{2}$	16949	14203
2 Parts of Salt of Tartar *per deliquium*, and 1 part of Spirit of Sal-armoniac		$8\frac{1}{5}$	60975	55209
2 Parts of a strong Solution of Nitre, and 1 part of Spirit of Sal-ammoniac, mix'd		52	9615	18965

OBSER-

Observations *on the* Tables.

Obs. 1. ANimal Fibres are stronger when they are dry, than when they are wet with any of the Fluids of theſe Tables.

Obs. 2. By the firſt Table, Fats and Oils ſtrengthen animal Fibres out of the Body more than ardent Spirits; ardent Spirits ſtrengthen them more or leſs, as they are more or leſs rectified; Cream of Cows Milk ſtrengthens them more than skim'd Milk, and fermented Liquors more than cold Water: But ardent Spirits and fermented Liquors of all Kinds are compoſed of Oil and Water united by Fermentation, the Water, by means of ſome ſaline Spirits with which 'tis impregnated, diſſolving

ſolving the Oil, and volatilizing it by the Action; Cream of Cows Milk contains more oily Parts than skim'd Milk; and even Water is not void of oily Parts, foraſmuch as out of it grow all vegetable and animal Subſtances which contain ſuch Parts in their Compoſition: And therefore it is rational to attribute the ſtrengthening Powers of all theſe Fluids to their oily Parts.

Obſ. 3. Dew, which is compoſed of watry Vapours condenſed, ſtrengthens animal Fibres little more than cold Water: But Salt of Tartar *per deliquium* ſtrengthens them much more than the ſtrongeſt Solution of the ſame Salt in cold Water: And therefore this Salt in deliquating draws ſomething out of the Air beſides Water. What that is, may be gathered from *Prop.* 24. and the following Chymical Experiments

ments and Inferences drawn from them.

"A Solution of Silver in *Aqua* " *fortis* poured upon Copper, dis- " solves the Copper and lets go the " Silver; a Solution of Copper " poured upon Iron, dissolves the " Iron and lets go the Copper; a " Solution of Iron poured upon *La-* " *pis Calaminaris* or Zink, dissolves " the *Lapis Calaminaris* or Zink " and lets go the Iron; a Solution " of Zink poured upon Chalk, " Crabs Eyes or Oyster-shells dis- " solves the Chalk, Crabs Eyes or " Oyster-shells and lets go the " Zink; a Solution of Chalk, Crabs " Eyes or Oyster-shells mix'd with " Spirit of Sal-armoniac, unites " with the Spirit and lets go the " Chalk, Crabs Eyes or Oyster- " shells; and this Mixture poured " upon Salt of Tartar *per deliquium*, " dissolves the Salt and lets go the

" volatile

" volatile Spirits. Hence the acid
" Particles of *Aqua fortis* are at-
" tracted more ſtrongly by Cop-
" per than by Silver, and more
" ſtrongly by Iron than by Copper,
" and more ſtrongly by *Lapis cala-*
" *minaris* or Zink than by Iron,
" and more ſtrongly by Chalk,
" Crabs Eyes or Oyſter-ſhells than
" by Zink, and more ſtrongly by
" Spirit of Sal-armoniac than by
" Chalk, Crabs Eyes or Oyſter-
" ſhells, and more ſtrongly by Salt
" of Tartar *per deliquium* than by
" Spirit of Sal-armoniac.

Hence it appears, that Salt of Tartar *per deliquium* attracts Acids more ſtrongly than Metals do, or any Body we know of: But the Air abounds with acid Particles, by *Prop.* 24: And therefore the watry Moiſture imbibed from the Air by this Salt when it deliquates, muſt neceſ-

sarily be strongly impregnated with acid Particles.

And if the Acid of the Air be the sole Cause of the great Excess of the strengthening Power of Salt of Tartar *per deliquium* above that of the strongest Solution of the same Salt in Water, as I think it must be allow'd to be; then such as receive most of that Acid into their Blood in a given Time, will, *cæteris paribus*, have the strongest Fibres. Hence animal Fibres are strongest in frosty Weather, are stronger in Winter than in Summer, in cold Countries than in hot, in dry Weather than in moist, and in Winds which blow from the *North* and *East*, than in Winds blowing from the *South* and *West*.

Obs. 4. By the second Table, Spirit of Sal-armoniac and Sheep's Gall,

Gall, lessen the strengthening Powers of Oils, ardent Spirits, Cream, and fermented Liquors; and the Spirit lessens them more than the Gall: But by the second Observation Oils, ardent Spirits, Cream, and fermented Liquors have their strengthening Powers from their oily Parts: And therefore Spirit of Sal-armoniac and Sheep's Gall must lessen the strengthening Powers of those Fluids by producing some Change in their oily Parts. Hence Gall in the Intestines of Animals, lessens the strengthening Power of the oily Part of the Aliment in its Passage thro' them.

Obs. 5. The Fats of Animals are rather more strengthening than Oil-Olive, which shews that the oily Part of the Nourishment regains in the Blood that Part of its strengthening Power which it loses in the Intestines by being mix'd with the

Gall: But the Acid of the Air has a very great ſtrengthening Power, by *Obſ.* 3; and the Blood of Animals has a conſtant Supply of this Acid by means of Reſpiration, by *Prop.* 24: And therefore it is rational to attribute the Recovery of the ſtrengthening Power of the oily Part of the Nouriſhment deſtroy'd by the Gall in the Inteſtines, to the Acid of the Air.

And if Oil, when its ſtrengthening Power is deſtroy'd or greatly leſſened by Gall, can recover it again by being mix'd with the Acid of the Air, we may allow this Acid to be the immediate Cauſe of the ſtrengthening Powers of Oils and all Fluids abounding with oily Parts. For Spirit of Sal-armoniac very much leſſens the ſtrengthening Powers of Oils and Fluids abounding with oily Parts, by the ſecond Table: But this Spirit attracts Acids very ſtrongly by the

the Experiments in *Obs.* 3: And therefore it is rational to think that it lessens the strengthening Powers of the said Fluids by drawing of an Acid from their oily Particles: This Acid must be the same with the volatile Acid of the Air which enters the Composition of all vegetable and animal Substances: And consequently Oils and Fluids abounding ing with oily Particles, have their strengthening Powers from the Acid of the Air united with those Particles. And that animal Fibres have their Strength from the same Cause will be shewn in the next Observation.

Obs. 6. Spirit of Sal-armoniac used alone weakens animal Fibres much more than cold Water; and it weakens them gradually, that is, if they be extended successively being suffered to contract after every Extension,

Extension, they will grow weaker in every succeeding Extension for a considerable Time. For an Hair kept wet with this Spirit, was weaker in the 25th Extension than in the first in the Proportion of 1 to 2; and another Hair kept wet with it, was weaker in the 60th Extension than in the first in the Proportion of 10 to 23. I try'd this last Hair four Days after when wet with the same Spirit, and found that it had not recovered any part of its lost Strength in that Time; but was then as weak in the first Extension, as it was in the 60th in the first Trial. Hence Spirit of Sal-armoniac gradually weakens the Power of the Cause upon which the Strength of animal Fibres depends: But this Spirit from its attracting Acids very strongly, greatly lessens the strengthening Power of oily Particles by drawing off the Acid of the Air from them,

them, by *Obſ.* 5; and animal Fibres contain an Acid in their Compoſition, foraſmuch as they contain Salt; and Salt is compoſed of Acid and Earth united by Attraction, as Sir *Iſaac Newton* has ſhewn, *Opt.* *p.* 360: And therefore Spirit of Sal-armoniac gradually leſſens the Strength of animal Fibres, by gradually drawing off an Acid from their earthy Parts, upon which Acid the Strength of Fibres depends. This Acid muſt be the ſame with the Acid of the Air, becauſe Animals have a conſtant Supply of this Acid both from their Food, and by means of Reſpiration.

Obſ. 7. The Juices of Water-Creſſes and Scurvy-Graſs, weaken animal Fibres ſomething more than cold Water, but much leſs than Spirit of Sal-armoniac; and they probably do it, as that Spirit does, by drawing

drawing off a ſmall Portion of the Acid from the earthy Parts of the Fibres.

Obſ. 8. Spirit of Vitriol weakens animal Fibres gradually, like Spirit of Sal-armoniac. For a Hair kept wet with this Spirit was weaker in the 12th Extenſion than in the firſt in the Proportion of 71 to 15. The Way this Spirit weakens animal Fibres may be this: The earthy Part of a Fibre may attract this Spirit more ſtrongly than its own Acid from whence it has its Strength, and not being able to hold both, may let go its own to cloſe with this, and ſo loſe its Strength. The Caſe here is much like that deſcribed by Sir *Iſaac Newton* in theſe Words. "When " Spirit of Vitriol poured upon " common Salt or Salt-petre makes " an Ebullition with the Salt and " unites with it, and in Diſtillation

" the

"the Spirit of the common Salt or
"Salt-petre comes over much easier
"than it would do before, and the
"acid Part of the Spirit of Vitriol
"stays behind; does not this argue
"that the fix'd Alcaly of the Salt
"attracts the acid Spirit of the Vi-
"triol more strongly than its own
"Spirit; and not being able to hold
"them both, lets go its own?
Opt. p. 353.

Obs. 9. Rectified Spirit of Wine strengthens animal Fibres at first much more than cold Water; but if Fibres be kept constantly wet with it, they will grow weaker in every Extension for some Time. For a Hair kept constantly wet with it, was weaker in the 24th Extension than in the first in the Proportion of 26 to 7; but it was then stronger than if it had been wet with Water in the Proportion of 35 to 26: So

that tho' Hairs wet with this Spirit grow weaker and weaker in every Extenſion, yet as far as I have try'd they never come to be ſo weak as when wet with Water. The Reaſon may be, that the ſpirituous Part of this Fluid evaporates much faſter than its watry Part: For this will leave the Hair more ſaturated with Water and leſs with Spirit in every ſucceeding Trial, and ſo gradually weaken it, tho' never ſo much as cold Water. The Strength of a Hair wet with this Spirit in the firſt Table, was taken from the firſt Extenſion, in which we may ſuppoſe the Hair to be moſtly ſaturated with this Spirit. But the Strengths of Hairs wet with Spirit of Sal-armoniac and Spirit of Vitriol were taken from the laſt Extenſions of the Trials I made, as they ought to be, on account of the Change made in the Texture of the Fibres by thoſe Spirits.

Obſ.

Obs. 10. Spirit of Sal-armoniac and the Gall of Animals ſcarce alter the ſtrengthening Power of the ſtrongeſt Solution of common Salt in Water; which argues that the acid Part of common Salt is more ſtrongly attracted by the Alcaly of that Salt, than it is by Spirit of Sal-armoniac and the Gall of Animals. Hence common Salt is of a very permanent Nature, and a great Preſerver of animal and vegetable Subſtances from Putrefaction when they are ſaturated with it.

Obſ. 11. Spirit of Sal-armoniac and the Gall of Animals mix'd with Salt of Tartar *per deliquium*, encreaſe its ſtrengthening Power; and this they do by imparting ſome Acid to that Salt. For Salt of Tartar *per deliquium* attracts Acids more ſtrongly than Spirit of Sal-armoniac does, by the Experiments in *Obſ.* 3;

 and

and consequently, by the stronger Attraction, it not only retains its own Acid, but draws some Acid from the Salts of the Spirit and Gall, and has its strengthening Power encreased thereby.

Obs. 12. Vegetable Juices taken one with another, strengthen animal Fibres something more than cold Water. The Juices of Fruits strengthen them something more than the Juices of Roots or Herbs; and the Juices of green Fruits a little more than the Juices of Fruits which are ripe. In general, vegetable Juices strengthen less than the Gravies of flesh Meats, and Water less than fermented Liquors; whence Persons who live upon flesh Meats and fermented Liquors have, *cæteris paribus*, stronger Fibres than Persons who live upon Vegetables and Water. Air is much worse, from putrid

putrid Vapours and Exhalations, in Cities than in the Country; on which account, a Diet of flesh Meats and fermented Liquors taken in moderate Quantities, is more necessary in Cities than in the Country, to strengthen the Fibres and preserve Bodies from Diseases. Fresh Air is a great Strengthener of the Fibres, and a great Preserver of animal Fluids from Putrefaction; and consequently does not require so generous a Diet to keep Bodies in Health, as an Air corrupted by putrid Vapours and Exhalations.

Obs. 13. So then, by the foregoing Observations, animal Fibres seem to have their Strength, and Fluids their strengthening Powers, from the Acid of the Air, united with their component Particles by virtue of its strong Attraction.

The

The Acid of the Air and other acid Spirits, ſeem to have their attractive Powers from the Particles of Light united with their component Particles. For Sir *Iſaac Newton* has ſhewn from Experiments and Obſervations, that both Acids and Light attract fix'd Bodies more ſtrongly than they do Water, that the attractive Powers of the Particles of Light in Proportion to their Quantities of Matter are exceedingly great, for Inſtance, the Attraction of a Ray of Light in Proportion to its Quantity of Matter, is above 1000000000000000 times greater than the Gravity of a Body at the Surface of the Earth is in Proportion to its Quantity of Matter, and that Light enters the Compoſition of all Bodies; from all which it is rational to attribute the attractive Powers of acid Particles to the Particles of Light united with them.

From

From the immenſe Attraction of the Rays of Light in Proportion to their Quantities of Matter, Sir *Iſaac Newton* makes the following Inference. " Tanta autem vis in Radiis, non " poteſt non ingentes effectus ob- " tinere in illis materiæ particulis, " quibuſcum in corporibus compo- " nendis conjuncti ſint; ad efficien- " dum, ut particulæ illæ ſe invicem " attrahant, et inter ſe moveantur. And he expreſſes much the ſame Opinion in *Qu.* 30. of his *Opticks* in theſe Words. " Are not groſs " Bodies and Light convertible into " one another, and may not Bodies " receive much of their Activity " from the Particles of Light " which enter their Compoſition? " For all fix'd Bodies being heated " emit Light ſo long as they con- " tinue ſufficiently hot, and Light " mutually ſtops in Bodies as often

" as

" as its Rays strike upon their Parts,
" as we shew'd above.

Obs. 14. Mr. *Hales* in his *Vegetable Staticks* has shewn that volatile Salt of Sal-armoniac distill'd absorbs true permanent Air, or destroys part of its Elasticity: But this Salt in Spirit of Sal-armoniac attracts Acids so strongly as to be able to draw them off from Metals and Earths dissolved by them, by the Experiments in *Obs.* 3; and the Particles of true permanent Air are of a fix'd and earthy Nature: And therefore it is rational to think, that the volatile Salts of Sal-armoniac distill'd absorb true permanent Air, or destroy its Elasticity, by drawing off an Acid from its component Particles. And if so, then the same Cause which gives the Particles of fix'd Bodies an attractive Power when they touch, whereby

whereby they ſtick together, gives them a repulſive Power whereby they fly or endeavour to fly aſunder, when by Heat or Fermentation they are removed to ſmall Diſtances from one another.

PROPOSITION XXXVI.

ANimal Fibres by Age encreaſe in Denſity and Strength, and leſſen a little in Magnitude.

Proof by EXPERIMENTS.

Experiment I.

THE mean Strengths of the Hairs of three Females of the Ages 8, 22, 57 Years, were as the Numbers 10309, 17967, and 25000,

when the Hairs were dry: And single Hairs of these Persons of the same Strength when dry, were of the Strengths 7812, 14285, and 22222, when they were wet with cold Water. The mean Densities of these Hairs were 10390, 11470, and 12947, the Density of Water being 10000. And their mean Diameters were $\frac{1}{300}$, $\frac{1}{317}$, and $\frac{1}{350}$ part of an Inch.

Exp. 2. The mean Diameter of the Hairs of 4 Girls, whose mean Age was seven Years and a half, was $\frac{1}{382}$ part of an Inch, and their mean Density 10348. And the mean Diameter of the Hairs of 4 old Women, whose mean Age was 58 Years, was $\frac{1}{398}$ part of an Inch, and their mean Density 12692. Therefore the *Proposition* is true.

Cor.

Cor. 1. The Strengths of animal Fibres in Proportion to their Densities, are less in young Bodies than in old. For the mean Strengths of the Hairs of the three Females in the first *Experiment* in Proportion to their mean Densities, are as the Numbers 99220, 156643, and 193095.

Cor. 2. The Strengths of animal Fibres in Proportion to the Quantities of Matter in equal Lengths of them, are less in young Bodies than in old. For the mean Quantities of Matter in equal Lengths of the Hairs used in the first *Experiment*, computed from their mean Diameters and mean Densities, are as the Numbers 11544, 11414, and 10568; and their mean Strengths in Proportion to their mean Quantities of Matter, are as the Numbers 89301, 157412, and 236563.

Scholium.

From Fibres growing ſtronger as Bodies grow older, without any Increaſe in their Quantities of Matter; it is evident that the Power which makes the Particles of Fibres to cohere and reſiſt extending Forces, muſt ariſe from ſome very ſubtile Matter, whoſe Particles are endued with very great attractive Forces; which ſubtile Matter can be no other than Light. For the Particles of Light, from their exceeding Smallneſs, may enter the Compoſition of Bodies in great Quantities without ſenſibly increaſing their Weights, and, from their ſtrong attractive Powers, may make the Particles of the Bodies with which they are united cohere or ſtick together with great Force. Hence Fibres will grow ſtronger perpetually as Bodies advance in Age, from their ſtill getting

ting more and more of theſe active Particles from Food, Exerciſe, Fire, and that great Fountain of Light the Sun; and conſequently Bodies will grow old ſooneſt, whoſe Fibres by the aforeſaid Ways get the greateſt Quantity of theſe active Particles into their Compoſition in a given Time. The Truth of all which appears from the following Obſervations. Old Woods burn more vehemently than young Woods of equal Dryneſs, which argues that they contain more Light in their Compoſition. Plants abound more with Oil and leſs with watry Juices, in Autumn than in Spring; but Oil contains much more Light in its Compoſition than Water. Women ſooner leave off Child-bearing, and Bodies grow old ſooner, in hot Countries than in cold. Plants of the ſame Kind ſooner come to their full Growth and wither ſooner in ſunſhiny

ſhiny than in ſhady Places. And violent Exerciſe brings on old Age, which conſiſts in an univerſal Hardneſs of the Fibres, as *Sanctorius* has obſerved. This Hardneſs of the Fibres cauſed by violent Exerciſe, may ariſe chiefly from a greater Quantity of Light imparted to them in a given Time, by a greater Quantity of Food and a greater Quantity of the Acid of the Air. For the watry part of the Food muſt communicate Light to the Fibres on account of their attracting it more ſtrongly than Water does, by *Obſ.* 13. *Prop.* 35. And if the Acid of the Air be of a watry Nature, and differ chiefly from Water in containing much more Light in its Compoſition than Water does, as from ſome Obſervations is obvious to collect, then this Acid will do the ſame as the watry part of the Food, and for the ſame Reaſon; and granting this, ſuch

ſuch as take moſt Food, and acquire moſt of this Acid by Reſpiration, in a given Time, muſt, *cæteris paribus*, have the ſtrongeſt Fibres: But ſuch as uſe violent Exerciſe, take more Food and more freſh Air than others: And conſequently they will ſooneſt acquire that Strength and Rigidity of the Fibres wherein old Age conſiſts.

PROPOSITION XXXVII.

THE Fibres of Animals are ſtronger or weaker, as the Air abounds, leſs or more with watry Vapours or putrid Exhalations, or more or leſs with acid Particles, or as it is colder or hotter.

1. The Fibres of Animals are ſtronger or weaker, as the Air abounds leſs or more with watry Vapours. For all Sorts of Fibres, and moſt other Bodies, are drier or moiſt-

er

er as the Air is drier or moister; Woods shrink and become lighter in dry Weather, and swell and grow heavier in wet Weather; and I have found Hairs stretched with a very small Weight to be shorter in dry Weather than in wet, in the Day than in the Night. A Friend made a Hygroscope of a Piece of Spunge throughly dried and counterpoised by a Weight equal to it in that State, and observed in general, that from the Sun-rising the Weight of the Spunge decreased till Noon or a little after, and, if the Weather was not moist, stood there till towards Evening, when it began to increase, and increased considerably in the Night; that when the Window was left open in the Evening or Night the Weight increased more; that it increased very much even in the Day on washing the Room next to the Closet where it hung, tho' the Door was

kept

kept lock'd; and that it always increaſed in wet Weather and decreaſed in dry Weather. And it has been found by ſtatical Experiments that human Bodies are lighter in dry Weather than in wet Weather, which argues that the Fibres of Animals are affected by the Weather as other Bodies are, or that they are drier or moiſter as the Air abounds leſs or more with watry Vapours: But dry Fibres are ſtronger than wet Fibres by *Tab.* 1. *Prop.* 35. A Hair was ſtronger when dry than when wet with cold Water in the Proportion of 100000 to 14285. I wet a Hair with cold Water, and then ſuffer'd it to dry, and found it to be ſtronger in the ſeventh Extenſion than in the firſt which was made immediately on leaving off wetting it, in the Proportion of 71 to 34; which ſhews that wet Fibres grow ſtronger as they grow drier: And therefore the Fi-

bres of Animals are ſtronger or weaker, as the Air abounds leſs or more with watry Vapours.

2. The Fibres of Animals are ſtronger or weaker as the Air abounds leſs or more with putrid Exhalations. For Salts become volatile by Putrefaction, by *Schol. Prop.* 29; and conſequently when the Bodies of Animals and Vegetables are diſſolved by Putrefaction, their Salts become volatile, and aſcending into the Air deſtroy ſome Part of its Acid and leſſen its Elaſticity, by virtue of the great Power wherewith they attract acid Particles, and on both theſe Accounts thoſe Salts weaken the Fibres of Animals more or leſs, as the Air abounds more or leſs with them. There may likewiſe be Differences in the Natures and Powers of theſe putrid Salts, by which when mix'd with the Blood of Animals they may act very differently both upon it and the

the Fibres, and ſo cauſe Epidemick Diſeaſes of various Kinds. But the Effects ariſing from the different Natures of theſe Salts, I leave to be determined by farther Experiments and Obſervations.

3. The Fibres of Animals are ſtronger or weaker as the Air abounds more or leſs with acid Particles. The Truth of this appears from the Obſervations on the *Tables* of *Prop*. 35.

4. The Fibres of Animals are ſtronger or weaker, as the Air is colder or hotter. For Cold condenſes animal Fibres as well as other Bodies by bringing their Parts nearer together, and Heat rarefies them by removing their Parts to greater Diſtances from one another: But the nearer the Parts of Fibres are to one another, the greater are the attractive Powers of thoſe Parts, all Attraction being ſtronger at leſs Diſtances than at greater; and the

greater the attractive Powers of the Parts of Fibres are, the greater is the Strength of the Fibres: And therefore the Fibres of Animals are ſtrengthened by Cold and weaken'd by Heat, and conſequently are ſtronger or weaker as the Air is colder or hotter. Accordingly I have found Hairs to be ſtronger in Winter than in Summer, and they are much ſtronger when wet with cold Water than when wet with hot Water, by *Tab.* 1. *Prop.* 35. Therefore the *Propoſition* is true.

Proposition XXXVIII.

If dry Fibres of different Strengths be wetted with Water, or Fibres wet with Water of different Strengths be dried; the Loſſes of Strength of the firſt in Proportion to their Strengths when dry, and the Gains of Strength of

of the second in Proportion to their Strengths when wet, will each of them be less in stronger Fibres than in weaker.

Proof by Experiments.

FIVE Hairs were extended by a given Weight in equal Times, thro' the Spaces 3, 4, 5, 6, 7, when the Hairs were dry; and thro' the Spaces $7\frac{1}{2}$, $12\frac{1}{2}$, 36, 60, 89, when they were wet with Water. Their Strengths computed from these Extensions, were as the Numbers 3333, 2500, 2000, 1666, 1428, when the Hairs were dry; and as the Numbers 1333, 800, 277, 166, 112, when they were wet. And their Losses of Strength by being wetted, were as the Numbers 2000, 1700, 1723, 1500, 1316; which Numbers likewise express the Gains of Strength which the wet Hairs would have acquired by being dried; for I have found that Hairs wet with Water

ter recover the same Degrees of Strength by being dried, which they lose by being wetted. And the Losses of Strength of the dry Hairs by being wetted, in Proportion to their Strengths when dry, were as the Numbers 6000, 6800, 8615, 9003, 9215: And the Gains of Strength of the wet Hairs by being dry'd, in Proportion to their Strengths when wet, were as the Numbers 1500, 2125, 6220, 9036, 11750. Therefore the *Proposition* is true.

Cor. Hence we see the Reason why Persons of weak Fibres are more affected by Changes of Weather from dry to wet and wet to dry, than Persons of strong Fibres. For those must certainly be most affected by these Changes, whose Fibres alter most in their Strength with respect to the Strength they had before the Changes happened. Accordingly we

we often find Persons of weak Fibres complain of Lowness of Spirits and Pains at the coming on of wet Weather, but seldom observe Persons of strong Fibres to be troubled with those Complaints.

Proposition XXXIX.

If the same Fibre both dry and wet be extended and contracted alternately for same Time, it will in both these States lose Part of its Strength by this Motion; and the Loss in a given Time in Proportion to the Strength at the Beginning of the Motion, will be less when the Fibre is dry, than when it is wet.

Proof by Experiments.

I Extended a dry Hair by a given Weight five times successively, taking off the appended Weight after every Extension, and suffering the

the Hair to contract as long as it was extending, which was two Minutes of Time. The first Extension was 5 and the last $5\frac{1}{2}$, whence by the first *Proposition* the Strength of the Hair in the first Extension was as 20000, and in the last as 18181; and the Loss of Strength by the Motion as 1819, and the Loss in Proportion to the Strength at the Beginning of the Motion as 909. After this, I wet the same Hair, and kept it wet during five other Extensions, the first of which was 64 and the last 93. The Degrees of Strength corresponding to these Extensions, were as the Numbers 1562 and 1075; and the Loss of Strength by the Motion in this State of the Fibre was as 487, and the Loss in Proportion to the Strength at the Beginning of the Motion as 3118.

I extended another Hair 7 times, both when it was dry and when it was

was wet with Water, and found the first and ſeventh Extenſions to be 6 and $6\frac{3}{4}$ when it was dry. The Strengths correſponding to theſe Extenſions were as the Numbers 16666, 14815, and the Loſs of Strength by the Motion as 1851, and the Loſs in Proportion to the Strength at the Beginning of the Motion, as 111. When the ſame Hair was wet, the first and ſeventh Extenſions were 85 and 102. The Strengths correſponding to theſe Extenſions were as the Numbers 1176, 980, and the Loſs of Strength by this Motion was as 196, and the Loſs in Proportion to the Strength at the Beginning of the Motion, as 166. Therefore the *Propoſition* is true.

Cor. Hence we have one Reaſon why ſpare dry Bodies are not ſo ſoon tired by Labour and Exerciſe, as Bodies which are groſs and phlegmatick. For the Fibres of the former

are drier than the Fibres of the latter; and consequently, by this *Proposition*, lose less Strength in a given Time in Proportion to their Strength at the Beginning of the Motion, than the others do: But those Bodies must certainly bear Labour and Exercise longest without Fatigue, whose Fibres lose least Strength in a given Time in Proportion to their Strength at the Beginning of the Motion. Another Reason why the former can bear Labour and Exercise longer without Fatigue than the latter, is, that they have lighter Bodies to move, and stronger Muscles to move them.

Proposition XL.

The Contraction of a Fibre in a given Time, in Proportion to its Extension caused by a given Weight in the same Time; is something less in stronger

ſtronger Fibres than in weaker, both when the Fibres are dry and when wet with Water.

Proof by EXPERIMENTS.

Exp. 1. THE Extenſions in 2 Minutes of 2 dry Hairs of a Girl 8 Years of Age, were 7, 21, and their Contractions in the ſame Time were $6\frac{5}{8}$, 20. And the Extenſions of the ſame Hairs when wet with Water were 72, 118; and their Contractions $71\frac{1}{4}$, 117. And the Contractions in Proportion to their reſpective Extenſions, were as the Numbers 9464, 9523 when the Hairs were dry, and as the Numbers 9895, 9915 when they were wet with Water.

Exp. 2. The Extenſions of 2 dry Hairs of a young Woman 22 Years of Age were $4\frac{1}{2}$, 8; and their Contractions in the ſame Time 4, $7\frac{1}{2}$: And the Extenſions of the ſame

Hairs when wet with Water were 15, 92; and their Contractions $14\frac{1}{8}$, $91\frac{1}{4}$. And their Contractions in Proportion to their respective Extensions were 8888, 9375 when the Hairs were dry, and 9417, 9918, when wet with Water.

Exp. 3. The Extensions of 2 dry Hairs of a Woman 57 Years of Age were 5, $13\frac{1}{2}$, and their Contractions in the same Time $4\frac{1}{2}$, $12\frac{3}{4}$. And the Extensions of the same Hairs when wet with Water were $22\frac{1}{2}$, 77, and their Contractions $21\frac{3}{4}$, $75\frac{3}{4}$. And their Contractions in Proportion to their respective Extensions were as the Numbers 9000, 9444 when the Hairs were dry, and as the Numbers 9666, 9838 when wet with Water. Therefore the *Proposition* is true.

FINIS.

A

CONTINUATION

OF A

TREATISE

OF THE

Animal Oeconomy.

To which is added, A

Letter to Dr. *Cheyne.*

CONTAINING,

An Account of the Motion of Water through Orifices and Pipes; and an Anſwer to Dr. *Morgan*'s Remarks on the firſt part of this TREATISE.

By BRYAN ROBINSON, M. D.

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[illegible] with Water were 92; and their Contractions [illegible] 91¼. And their Contractions in Proportion to their respective [illegible] were 88, 93,5 when Hairs were dry, and 84.7, 99 when wet with Water.

[illegible] The Extensions of the Hairs of a Woman 57 Years of Age were 5, 13½, and their Contractions in the same Time 4½, 12¼. And the Extensions of the same Hairs when wet with Water were [illegible], and their Contractions 4¼, [illegible] And their Contractions in Proportion to their respective Extensions [illegible] when the Hairs were dry, are [illegible] Numbers 9666, 9838 when wet with Water. Therefore the Proposition is true.

FINIS.

Advertiſement.

IN *this Continuation of the* Animal Oeconomy, *I have given an Account of the Tenacity of the Blood compared with the Strength of the Fibres; of the vibrating Motions of the Fibres, and Motions of the Fluids conſequent thereon; and of the proper Methods of regulating Exceſſes and Defects in any of theſe, in order to reduce them to a natural State; whether the Deviation from that State conſtitutes an* acute *or a* chronical Diſeaſe.

Aug. 22. 1737.

ERRATA.

P. 10. *l.* 5. *for* If A *r.* If a. *p.* 16. *l.* 20. *and p.* 17. *l.* 2. *for* $\frac{Q}{.7853816D^2T}$ *r.* $\frac{Q}{.785398 16D^2T}$ *ibid. for* $67.97239 \sqrt{\frac{A^2H}{A^2-a^2}}$ *r.* $53.3854 D^2T \sqrt{\frac{A^2H}{A^2-a^2}}$, *and for* $W=53.38426D^2T\sqrt{\frac{A^2H}{A^2-a^2}}$ *r.* $W=28.1756\ D^2T\sqrt{\frac{A^2H}{A^2-a^2}}$. *p.* 32. *l.* 8. *for* inside *r.* Side. *ibid. l.* 11. *for* Water. *r.* Water: And therefore the Force generating the Motion of Water flowing through a Pipe is equal to the Weight of a Cylinder of Water whose Magnitude is $a \times \frac{A^2H}{A^2-a^2}$, and is proportional to $D^2 \times \frac{A^2H}{A^2-a^2}$. However I will grant that F is ever as D^2H, and accordingly consider the Consequences he draws from it. *p.* 33. *l.* 3. *del.* ing. *p.* 50. *l.* 12. *for* ascalious *r.* alcalious.

SECTION V.

Of the Tenacity of the Blood compared with the Strength of the Fibres; of the vibrating Motions of the Fibres and the Motions of the Fluids consequent thereon; and the proper Methods of regulating the Excesses and Defects in any of these in order to reduce them to a natural State.

PROPOSITION XLI.

THE Tenacity of the Blood is increased by Things which strengthen the Fibres, and lessened by Things which weaken them.

1. Cold ſtrengthens and Heat weakens animal Fibres, by *Prop.* 37. And Cold increaſes and Heat leſſens the Tenacity of the Blood. For Cold condenſes and Heat rarefies the Blood: But when the Blood is condenſed, its Particles are brought nearer together, and when it is rarefied, they are removed farther aſunder; and when the Particles of the Blood are brought nearer together, their attractive Forces are increaſed, and when they are removed farther aſunder, thoſe Forces are leſſened, all attractive Forces being ſtronger at leſs Diſtances than at greater; and when the attractive Forces of the Particles of the Blood are increaſed or leſſened, the Coheſion of thoſe Particles, which meaſures the Tenacity of the Blood, is increaſed or leſſened: And therefore Cold increaſes and Heat leſſens the Tenacity of the Blood.

These Effects of Heat and Cold on the Blood are the ſame with their Effects on other Bodies. Heat promotes Fluidity very much by leſſening the Tenacity of Bodies. It makes many Bodies fluid which are not fluid in Cold, as Metals, Butter, Fat of Animals, Jelly, and Soap; and increaſes the Fluidity of tenacious Liquids, as of Oil, Balſam, Honey, Mucilage, and a ſtrong Solution of Soap in Water. Mucilage and a ſtrong Solution of Soap in Water, which are very tenacious and ropy when cold, preſently loſe their Tenacity when ſet on the Fire, but do not loſe it while they continue cold, though they be ſtrongly agitated with the Hand or any other Way.

2. Drineſs ſtrengthens and watry Moiſture weakens animal Fibres, for the very ſame Reaſon that Cold ſtrengthens and Heat weakens them.

For

For all Fibres both vegetable and animal ſwell in wet Weather, and contract in dry Weather: But when Fibres ſwell by the Force of watry Moiſture imbibed, their component Particles are removed farther aſunder, and of Conſequence, the attractive Powers of thoſe Particles, and the Strength of the Fibres depending on them, are leſſened; and on the contrary, when the Fibres contract on the Evaporation of the imbibed Moiſture, their Particles are brought nearer together, and their attractive Forces, on which the Strength of the Fibres depends, are increaſed. By the ſame way of reaſoning, the Blood muſt be more or leſs tenacious, as it abounds leſs or more with Water. For a greater Proportion of Water in the Blood removes its ſtrongly attracting Particles to greater Diſtances from one another, and conſequently, leſſens their

their attractive Powers and the Tenacity of the Blood depending on thoſe Powers; and a leſſer Proportion of Water in the Blood has a contrary Effect on its Tenacity. And therefore, Drineſs increaſes and watry Moiſture leſſens the Tenacity of the Blood.

3. Oils, ardent Spirits, and all Liquors abounding with oily Parts ſtrengthen animal Fibres, and warm Water and alcalious Spirits weaken them, by *Table* 1. *Prop.* 35. And by Experiments made on the Blood it has been found, that Oils, ardent Spirits, Balſams, and Bitters increaſe the Tenacity of the Blood; and that warm Water and alcalious Spirits leſſen it. Hence it is, that Spirit of Harts-horn, when taken in too large a Quantity, has been found to occaſion Hæmorrhages; and that the Blood coagulated by the Bites of venomous Creatures recovers its natural

tural Fluidity by large Doſes of volatile alcalious Spirits given in Fountain Water, without any other Remedy.

4. The Acid of the Air ſtrengthens animal Fibres, by the Obſervations on the *Tables* in *Prop.* 35. And that it gives a Tenacity and Conſiſtence to the Blood, may be gathered from its Manner of acting both on the Salts and oily Parts of the Blood.

The Acid of the Air, after it is taken into the Blood, unites with its Salts, and thereby renders them groſſer and leſs volatile than before; in like Manner as Spirit of Sea-ſalt which is an acid Spirit, and Spirit of Soot which is a volatile alcalious Spirit, being mix'd together unite and compoſe the Particles of Sal-armoniac, which are groſſer and leſs volatile than before: But volatile alcalious Spirits, which are compoſed

posed of volatile alcalious Salts and Water, greatly attenuate and thin the Blood, by *N.* 3: And therefore the Acid of the Air, by changing the Salts of the Blood as they become volatile by Heat or Putrefaction into a Kind of Sal-armoniac, and thereby lessening their Volatility, keeps up a Tenacity in the Blood.

Hence the Blood will be apt to abound with volatile Salt, when it is not sufficiently impregnated with this Acid; and it may not be sufficiently impregnated with this Acid, when the Air is not sufficiently stock'd with it, or when too small a Quantity of it is taken into the Blood in a given Time by Respiration. The Air contains less of this Acid in hot Weather than in cold Weather, Part of it being destroy'd in hot Weather by the great Quantities of sulphureous Steams and vo-

latile Salts, which are then raiſed from the Earth and the putrified Subſtances of Vegetables and Animals; and Perſons who are inactive, by breathing leſs receive leſs of it into their Blood in a given Time than Perſons who uſe Exerciſe. Hence putrid Fevers are much more frequent in Summer and hot Climates than in Winter and cold Climates; and oftener ſeize ſedentary Perſons than Perſons who uſe Exerciſe. Hence likewiſe the Fleſh of Fiſh, from their breathing leſs and conſequently taking leſs of the Acid of the Air into their Blood in a given Time than Land Animals, is of a more alcalious Nature and corrupts ſooner than the Fleſh of Land Animals. In a *Phthiſis* the Blood abounds with volatile Salts, and conſtant Riding (by which the Blood is plentifully ſupply'd with this Acid) is

is found to be of the greateſt Service in its Cure.

The Acid of the Air, by giving Strength to the Fibres and a Tenacity to the Juices, greatly preſerves animal Subſtances from Putrefaction. For thoſe Subſtances putrify ſooneſt, whoſe Fibres are weakeſt and Fluids leaſt tenacious. Young Meats of all Kinds, whether Fleſh or Fiſh, corrupt ſooner than old; the Fleſh of Fiſh corrupts ſooner than the Fleſh of Land Animals; the ſofteſt and moiſteſt Fleſh of all Kinds corrupts generally ſooneſt; the Fleſh of Land Animals, kill'd ſoon after they have been much heated by hunting or hard driving, corrupts much ſooner than the Fleſh of Animals not ſo uſed; and all Sorts of Fleſh corrupt ſooner in hot Weather than in cold Weather, in moiſt Weather than in dry Weather, and in a ſtagnating Air than in an Air agi-

tated by Wind. The Salts of the Blood are too volatile in putrid Fevers, and accordingly, their Cure is most successfully effected by gentle Sweats and Liquids impregnated with Acids. Gentle Sweats carry off Part of the volatile Salt, and acidulated Liquids correct the Remainder. *Sydenham* cured a Pestilential Fever by Sweating. And the Child-bed Fevers of Women are best cured by keeping them constantly in a gentle Sweat, by slightly-acidulated Drinks taken warm. The great Heat, occasioned by the *Labour*, volatilizes the Salt and Oil of the Blood, and thereby makes Child-bed Fevers to be of the putrid Kind.

On the contrary, the Blood is more than ordinarily tenacious and viscid in inflammatory Fevers, which are most frequent in cold frosty Weather, in which the Air abounds most with acid Particles, and the Blood

Blood of Consequence is most saturated with them; and oftener seize Persons who use much Exercise than Persons who are sedentary. That the Tenacity of the Blood in these Fevers arises in a good measure from its being impregnated with too great a Quantity of Acid, may be farther confirmed from their Cure, which is best effected, after due Evacuations in the Beginning, by alcalious Powders and Spirits, watry Liquors drunk warm, and warm Applications of a watry Nature to the inflamed Parts. These Things, from their Power of destroying Acids, of weakening the Fibres, and attenuating the Blood by their Warmth and watry Nature, are the proper Remedies in inflammatory Fevers.

The Acid of the Air gives a farther Tenacity and Consistence to the Blood, by its Action on the oily Parts of the Blood. The Fat of Land

Land Animals is harder, and consequently more tenacious than the Fat of Fish which runs much to Oil; and the former imbibe more of the Acid of the Air in a given Time than the latter. The oily Part of the Aliment, by being mixed with the Acid of the Air in the Blood, regains that Part of its strengthening Power which it loses in the Intestines by being mix'd with the Bile, by *Obs.* 5. *Prop.* 35. These Instances prove, that the Tenacity of the oily Part of the Blood, and consequently the Tenacity of the Blood which depends much on its oily Part, is increased by the Acid of the Air united with it. The Acid of the Air, when it first enters the Blood, attenuates and dissolves it with Heat, by *Prop.* 24. But after that Action is over, it unites with the oily Parts of the Blood, and by increasing their attractive Powers gives

gives it a Tenacity and Conſiſtence.

From what has been ſaid we may underſtand, whence it is, that the Diſcharges by Perſpiration, Urine and Stool, are more uniform and regular and leſs apt to run into Exceſſes and Diſproportions to one another, in Perſons who uſe conſtant and moderate Exerciſe in the open Air, than in Perſons who are indolent and ſit much within Doors. The former imbibe more of the Acid of the Air in a given Time, and conſequently acquire a greater Tenacity and Conſiſtence of the Blood and Juices than the latter; but the more tenacious and conſiſtent the Blood and Juices are, the leſs apt their Parts will be to ſeparate and run off by exceſſive and diſproportionate Diſcharges. The Diſcharges are very irregular in Hyſterical and Hypochondriacal Perſons, who

who commonly are sedentary and inactive; and nothing restores them to a just Proportion and Uniformity so much as constant and moderate Exercise in the open Air.

5. A strong Solution of common Salt in Water is a great Strengthener of animal Fibres, by *Tab.* 1. *Prop.* 35. And that common Salt increases the Tenacity of the Blood, appears from its preserving the Flesh and Juices of Animals from Putrefaction.

6. Animal Fibres grow harder and stronger by Age, by *Prop.* 36. And we find by Observation, that the Blood of old Animals is more thick and tenacious than the Blood of young Animals. The Increase of Strength in animal Fibres by Age is to be ascribed to an Increase of the Quantity of the Particles of Light in their Composition, by *Schol. Prop.* 36. And the Increase

of

of the Tenacity of the Blood by Age muſt be owing to the ſame Cauſe which increaſes the Strength of the Fibres. For the Juices and Blood of old Plants and old Animals contain more Oil and leſs Water in their Compoſition than the Juices and Blood of young Plants and young Animals; but Oil contains much more Light in its Compoſition than Water, Quantity for Quantity.

Now ſince in the Inſtances above alledged of Heat and Cold, Drineſs and Moiſture, Oils, ardent Spirits, Balſams and Bitters, volatile and alcalious Subſtances, Water, the Acid of the Air, a ſtrong Solution of common Salt, and the Rays of Light; I ſay, ſince in theſe Inſtances, thoſe Things which increaſe the Strength of animal Fibres increaſe likewiſe the Tenacity of the Blood; and thoſe Things which leſſen the

Strength of animal Fibres leſſen alſo the Tenacity of the Blood; and ſince theſe are the Things which principally affect the Strength and Tenacity of the Fibres and Blood, and into which almoſt all Things which are any way capable of affecting the Strength and Tenacity of the Fibres and Fluids may be reſolved; it is therefore reaſonable to infer the Truth of the *Propoſition* univerſally.

Cor. 1. Hence, the Fibres are weaker and the Blood leſs tenacious in Perſons who live upon Vegetables and Water, than in Perſons who live upon Fleſh Meat and fermented Liquors; and hence alſo, the Fibres are weaker and the Blood leſs tenacious, *cæteris paribus*, in Perſons who are inactive than in Perſons who uſe Exerciſe.

Cor. 2. Hence, when the Tenacity of the Blood is too great or too little, we may know how to change it; for it will be leſſened by Things which weaken the Fibres, and increaſed by Things which ſtrengthen them.

SCHOLIUM.

The Tables in *Prop.* 35. exhibit the ſtrengthening Powers of various Fluids compared with one another, but do not ſhew, which of thoſe Fluids do really ſtrengthen or weaken the Fibres in the Bodies of living Animals. To know this, we muſt firſt know the ſtrengthening Powers of the animal Fluids, which may be had from the Strengths of Hairs wet with them, and then by comparing thoſe Powers with the ſtrengthening Powers of other Fluids we may

know, whether those other Fluids will strengthen or weaken the Fibres. To know the strengthening Powers of the animal Fluids, I took the Strengths of Hairs wet with the *Serum* of the Blood, the Saliva and Urine of a healthful Man, and with the Gall of a Sheep and of a Pig, when all these Fluids were cold; and found the Strengths of the Hairs wet with the three first to be as the Numbers 13888, 13244, 13950, and the Strengths of the Hairs wet with the two last to be equal, and as the Number 13888, which is a little less than the Strength of the Hair wet with the Gall of a Sheep in the first *Table*. From these Experiments it appears, that the strengthening Powers of the animal Fluids, when cold, are nearly equal to one another, and all nearly equal to 14285, which expresses the strengthening Power of cold Water. Hence

we may infer, that the ſtrengthening Powers of the animal Fluids, when warm in the Bodies of living Animals, are nearly equal to the ſtrengthening Power of Water under the ſame Degree of Warmth. And ſince cold Water is much more ſtrengthening than hot Water, and by Conſequence, the animal Fluids when cold more ſtrengthening than the ſame Fluids warm, we muſt allow, that all the Fluids of *Tab.* 1. (except volatile alcalious Spirits) when taken cold into the Bodies of Animals, are of a ſtrengthening Nature; and that the only Fluids which are remarkably weakening are volatile alcalious Spirits, and Water or watry Liquors taken hot.

I ſhall here ſet down the Strengths of Hairs wet with a few Fluids not mentioned in the *Table*. The Strengths of three Hairs wet with *Spiritus*

Spiritus salis volatilis oleosus, *Elixir proprietatis*, and *Aqua mirabilis*, were as the Numbers 65625, 65223, and 52083. The Strengths of four Hairs wet with strong Decoctions of the *Peruvian* Bark, *Gentian* Root, Chamomile Flowers, and Oak Bark, in Water, were as the Numbers 23809, 20000, 15873, and 15625. The Strengths of two Hairs, wet with *Elixir vitrioli Mynsichti* and *Tinctura martis Mynsichti*, were equal and as the Number 98000. The Strength of a Hair wet with *German Spa* Water as the Number 25000. And the Strength of a Hair wet with a strong Solution of *Opium* as the Number 15151. These Experiments were made at the same Time with those, from which I composed the first *Table* in *Prop*. 35. and with Hairs of the same Person; all which Hairs were equally strong when dry.

PRO-

PROPOSITION XLII.

IF an animal Fibre be extended and contracted alternately, without Intermission or Interval between the two Motions, by the alternate Action of an extending and contracting Force, if the two Forces be equal, and if all the Extensions and Contractions caused by those equal Forces be small, equal in Length, and described in equal Times; the vibrating Motion of the Fibre generated in a given Time, will be nearly as the Quantity of Matter in the Fibre and Length of one Extension taken together directly, and as the Time of one Extension inversly; or nearly, as the Quantity of Matter in the Fibre, the extending Force and Length of the Fibre taken together directly, and as the

the Resistance given to the Motion the Strength of the Fibre and Square of its Diameter, taken together inversly. If M *denote the vibrating Motion of the Fibre generated in a given Time,* q *the Quantity of Matter in the Fibre,* E *the Length and* t *the Time of one Extension,* l *the Length* d *the Diameter and* S *the Strength of the Fibre,* F *the extending Force, and* R *the Resistance given to the Motion; then* M *will be nearly as* $\frac{qE}{t}$, *or nearly as* $\frac{qFl}{RSd^2}$.

For, the Extensions and Contractions being small by Supposition, the vibrating Motion of the Fibre generated in a given Time, will be nearly as the Quantity of Matter in the Fibre and the Sum of all the Extensions and Contractions described in that Time, taken together: But the Extensions and Contractions

tractions are all equal and all described in equal Times by Supposition; and consequently, the Sum of all the Extensions and Contractions in the given Time will be as the Sum of all the Extensions; and the Sum of all the Extensions will be as the Length of one Extension and Number of Extensions in the given Time, taken together; and the Number of Extensions in the given Time will be inversly as the Time of one Extension; And therefore, the vibrating Motion of the Fibre generated in a given Time will be nearly as the Quantity of Matter in the Fibre and Length of one Extension taken together directly, and as the Time of one Extension inversly; that is, M will be nearly as $\frac{qE}{t}$. The Length of a small Extension of an animal Fibre is nearly as the extending

Force, the Time of the Extension, and Length of the Fibre taken together directly, and as the Resistance given to the Motion, the Strength of the Fibre, and Square of its Diameter taken together inversly, as I have found from Experiments; that is, E is nearly as $\frac{Ftl}{RSd^2}$: And therefore, M will be nearly as $\frac{qFl}{RSd^2}$.

Cor. 1. If the Quantity of Matter in an animal Fibre, its Diameter, and Length be all given; the vibrating Motion generated in a given Time will be directly as the extending Force, and inversly as the Resistance given to the Motion, and the Strength of the Fibre, taken together. If q, d and l be given, M will be nearly as $\frac{F}{RS}$.

To

To know how to increaſe or leſſen the vibrating Motion of the Fibres in animal Bodies, and in what Caſes and under what Circumſtances it will be proper to do the one or the other, are Matters of the utmoſt Importance in Phyſick.

To know how to increaſe or leſſen the vibrating Motion of the Fibres in animal Bodies, we muſt know the extending Force, the Reſiſtance given to the Motion, and the Strength of the Fibres; the Things which regulate that Motion, when q, d, and l are given.

The principal extending Forces of the Fibres in animal Bodies are Heat, the *Stimulus* of irritating Matter, and the Power of the Soul.

That Heat has a Power of cauſing a vibrating Motion in the Fibres of Animals, will appear from the following Obſervations. The Pulſe is fuller and quicker, and con-

sequently, the vibrating Motion of the Fibres of the Heart and Arteries greater, in Bodies heated by Exercise or an ardent Fever, than in Bodies chill'd by cold Air or the cold Fit of an Ague. The Fulness and Quickness of the Pulse lessen, as Bodies heated by Exercise grow cool. And in a Heart which continues to beat for some time after it is taken out of the Body, the Pulsations lessen both in Magnitude and Frequency as the Heat lessens, and cease when the Heat ceases. The Operation of vomiting and purging Medicines is increased by Heat and lessened by Cold: But Vomiting and Purging are caused by a strong vibrating Motion of the Fibres of the Stomach and Intestines: And therefore, Heat increases and Cold lessens the vibrating Motion of the Fibres of the Stomach and Intestines. Perspiration is much greater when the

Skin is warm than when it is cold. The *Catamenia* are increaſed by Heat, and leſſened, nay often intirely ſtopped, by Cold. In a Word, the progreſſive Motion of all the animal Fluids, which Motion is all cauſed by the vibrating Motion of the Fibres, is increaſed by Heat and leſſened by Cold.

The Diſcharges cauſed by the ſtimulating Particles of evacuating Medicines of all Kinds, of Poiſons, and of vegetable and animal Subſtances diſſolved by Putrefaction, ſhew that the *Stimulus* of irritating Particles has a Power of cauſing a vibrating Motion in the Fibres; for all progreſſive Motions of the Fluids, and all Diſcharges conſequent on thoſe Motions, are cauſed by the vibrating Motions of the Fibres.

The Soul has a great Power over the Motion of the Heart, by *Prop.* 21; and a ſtill greater Power over the

the Muscles designed for voluntary Motion, by every one's Experience; and besides, by a great Variety of powerful Instincts it regulates the Motions of the Fibres and Fluids, when they happen to be disturbed; and exerts such Efforts as are necessary to preserve animal Life. And therefore, the Soul has a Power of causing a vibrating Motion in animal Fibres.

The Resistance given to the vibrating Motion of the Fibres in Animals arises, either from the Fluids to be moved by that vibrating Motion, or from an Impediment or Check given to the Extension of the Fibres. An Increase of the Quantity or Tenacity of the Fluids, or an Impediment given to the Dilatation of the Vessels by Fat or any other Cause, will increase the Resistance; and a Diminution of the Quantity or Tenacity of the Fluids, or

or a Removal of an Impediment given to the Dilatation of the Veſſels, will leſſen the Reſiſtance.

The Strength of the Fibres may be known from the Food, Exerciſe, Age, and Habit of the Body. The Fibres are ſtronger in Perſons who live upon a ſtrengthening Diet, than in Perſons who live upon a weakening Diet; in Perſons who live upon Fleſh Meats and fermented Liquors, than in Perſons who live upon Vegetables and Water. We may know the Strength of the Fibres as far as it depends on Diet, by *Prop.* 35. The Fibres are ſtronger in Perſons who uſe Exerciſe, than in Perſons who are inactive; and in Perſons who uſe Exerciſe, the Fibres are generally ſtronger or weaker, as the Exerciſe requires more or leſs Motion of the Muſcles. The Fibres of old Bodies are ſtronger than the Fibres of young Bodies. And the Fibres

are

are ſtronger in lean Bodies than in fat Bodies, becauſe the Fibres are drier in lean Bodies than in fat Bodies, and drier Fibres are always ſtronger, *cæteris paribus*, than Fibres which are moiſter.

When the extending Force of animal Fibres, the Reſiſtance given to their vibrating Motion, and their Degree of Strength are once known; we may by this *Corollary* know, how to increaſe or leſſen the Motion. The vibrating Motion will be increaſed or leſſened, by increaſing or leſſening the extending Force, or by leſſening or increaſing the Reſiſtance, or the Strength of the Fibres. M will be increaſed or leſſened, by increaſing or leſſening F, or by leſſening or increaſing R or S.

To know, in what Caſes and under what Circumſtances it will be proper to increaſe or leſſen the vibrating Motion of the Fibres, when it

it happens to differ from that which obtains in a State of Health, we muſt know the Cauſe of that Motion, and the Intent of Nature in raiſing it. If the Cauſe be irritating Matter, and the Intent of Nature in raiſing a ſtrong vibrating Motion of the Fibres be to have that Matter carry'd out of the Body; the Motion muſt not be check'd, but be ſuffer'd to continue, and be increaſed, if there be Occaſion and the Strength can bear it, till that End is attained. And after that, if the vibrating Motion of the Fibres does not ceaſe of itſelf, it may be ſafely ſtopped by Things which ſtrengthen the Fibres and by *Opium*. For tho' *Opium* has no ſtrengthening Quality in it ſelf, yet foraſmuch as it eaſes Pain, and checks Diſcharges, it powerfully leſſens the vibrating Motion of the Fibres. The Truth

of theſe Things will appear from the following Inſtances.

A great vibrating Motion of the Fibres of the Stomach and Inteſtines, excited by vomiting and purging Medicines, Poiſons, corrupted Aliment, or ſharp Humours ſecerned from the Blood, muſt, if the Strength can bear it, be ſuffer'd to continue, and be increaſed (if there be Occaſion) by watry Liquors drunk plentifully and warm, till the irritating Matter is carried out of the Body by Vomit and Stool. And when this End is attained, if the vibrating Motion does not ceaſe of it ſelf, it may then be ſafely quieted by ſtrengthening Things and *Opium*. A ſtrong Solution of common Salt in Water, given in ſmall Quantities, powerfully ſtops vomiting; and it does it more effectually with an Addition of *Opium*. And compound Waters, which

which are ardent Spirits, and *Opium* powerfully ſtop purging. This Method has been found ſucceſsful in a *Cholera morbus*, and in a *Diarrhæa* and *Dyſentery* in the Beginning. But if a *Diarrhæa* or *Dyſentery* have been of ſome Continuance, the Flux muſt be ſtopped, not barely by ſtrengthening the Fibres, leſt Inflammations and Mortifications ſhould enſue, but chiefly by turning the Courſe of the Fluids from the Inteſtines to other Parts of the Body (the Manner of doing which ſhall be ſhewn hereafter) and likewiſe by correcting the ill Qualities of the Blood, which is generally much vitiated in long Fluxes of the Belly.

A great vibrating Motion of the Fibres of the Heart and Arteries, occaſioned by the Heat and Foulneſs of the Blood in Fevers, muſt not be check'd, unleſs ſome noble Part be

inflamed; but be kept up by Warmth and watry Liquids taken in proper Quantities, that the febrile Matter may be rightly concocted, intirely separated from the Blood, and discharged out of the Body in a *Crisis*. That the Blood is foul at the coming on of Fevers, appears from the Foulness of the Discharges in the *Crisis*, and the Termination of the Fever by those foul Discharges. And that Heat and Motion are the chief Instruments Nature uses to concoct the febrile Matter, and fit it to be separated from the Blood, and carried out of the Body by the Discharges, appears from those Fevers terminating soonest in which the Heat and Motion of the Blood are greatest, and those on the contrary latest in which the Heat and Motion of the Blood are least. The Heat and Motion of the Blood may be known by the Heat of the Skin all

over

over the Body, and the Magnitude and Frequency of the Pulſe.

Cor. 2. If the Quantity of Matter in the Fibre, its Diameter and Length, the extending Force, and the Reſiſtance to the Motion, be all given; the vibrating Motion of the Fibre generated in a given Time will be inverſly as the Strength of the Fibre. If q, d, l, F and R be given, M will be as $\frac{1}{S}$.

The Operation of a given Doſe of a vomiting or purging Medicine, cauſed by the given *Stimulus* of the Medicine, is much increaſed in one and the ſame Body by weakening the Fibres with Water and watry Liquors drunk warm. The Ancients prepared Bodies for vomiting and purging, by thinning the Humours and weakening the Fibres; both of which are neceſſary to make even a ſtrong

ſtrong Medicine produce a large Diſcharge in Perſons of robuſt and ſtrong Fibres.

Cor 3. If the Quantity of Matter in the Fibre, its Diameter and Length, the extending Force, Extenſion and Reſiſtance, be all given; the Time of an Extenſion will be as the Strength of the Fibre. If q, d, l, F, E and R be all given, t will be as S.

For ſince the Extenſion produced by a given extending Force in a given Time, is greater in one and the ſame Fibre when it is weak than when it is ſtrong; it follows, that the ſame extending Force will take up leſs Time in cauſing a given Extenſion in the ſame Fibre when weak than when ſtrong; and conſequently, the Time of producing a given Extenſion will vary with the Strength of the Fibre.

That

That the vibrating Motion of animal Fibres is made quicker by Things which weaken the Fibres, and ſlower by Things which ſtrengthen them, may be farther illuſtrated from the following Experiments.

I wet a Hair with Water, extended it when wet 90 Diviſions of the Scale, then let it dry, and kept it 24 Hours in that extended State. At the End of that Time, I removed all but 7 Grains of the Force which kept it extended, and it contracted 13 Diviſions in half an Hour, 5 more in 3 Hours, 5 more in 9 Hours and 40 Minutes, and 1 more in 12 Hours; ſo that in 24 Hours it contracted only 24, which was little more than a fourth Part of the whole Extenſion. I then apply'd a dry Cloth hot, and repeated the Application as often as the Cloth grew cool, on which it contracted

19 Divisions in 15 Minutes, and on wetting it with cold Water 43 more in 4 Minutes, and $1\frac{1}{4}$ more in 10 Minutes; so that by the Assistance of Warmth and Water it contracted near thrice as much in half an Hour, as it contracted in 24 Hours before.

I wet another Hair with Water, extended it when wet 90 Divisions of the Scale, then let it dry, and kept it 10 Days in that extended State. At the End of that Time, I took away all but 7 Grains of the Force which kept it extended, upon which it contracted 13 Divisions in half an Hour, 6 more in 4 Hours, 7 more in $21\frac{1}{2}$ Hours, 5 more in one natural Day and 2 Hours, 4 more in 4 Days and 16 Hours, $2\frac{1}{2}$ in two Days and one Hour, and $\frac{1}{2}$ more in one Day and three Hours; so that in 10 Days it contracted only 38, which was not half of the whole

whole Extension. I then held it to the Fire, upon which it contracted 12 in 3 Minutes; and 39 in 3 Minutes more, on wetting it with cold Water.

I again wet the Hair, used in the last Experiment, with Water, and kept it 10 Days extended 90 Divisions of the Scale. I then suffer'd it to contract, and it contracted 47 Divisions in 9 Days. During the Time of its Contraction the Weather was wet, which made it to contract more in 9 Days, than it did in 10 Days in the last Experiment when the Weather was drier. After that I held it to the Fire, on which it contracted $9\frac{1}{2}$ in 6 Minutes. Then I wet it with Oil, on which it was so far from contracting that it extended about 2 Divisions in 2 Hours, and continued so extended 24 Hours. I then wash'd the Hair with a Feather dipt in cold Water, and found, that

tho' it did not move immediately, yet in 7 Minutes from the Time I began to wash it, it contracted $30\frac{1}{2}$, and 2 more in 20 Minutes.

From these Experiments, Warmth and Water accelerate, and Oil retards the vibrating Motion of animal Fibres.

Cor. 4. If the extending Force be as the Quantity of Matter in the Fibre and the Length of one Extension, taken together; the vibrating Motion generated in a given Time will be as the extending Force directly, and the Time of an Extension inversly. If F be as q E, M will be as $\frac{F}{t}$.

The Force of the Heart is the extending Force of the System of Arteries, and if this Force be proportional to the Quantity of Matter contained in the Coats of the System

System and the Extension of the System in one Systole of the Heart, taken together; the vibrating Motion of the System generated by the Force of the Heart in a given Time, will be directly as the Force of the Heart and Number of Pulses in that Time taken together; or directly, as the Capacity of the System and Number of Pulses in that Time taken together, by *Prop.* 12; or directly, as the Quantity of Blood which flows through the Heart or Aorta in that Time, by *Cor.* 1. *Prop.* 14; or as the Sum of the Discharges by Perspiration Urine and Stool in that Time, by *Cor.* 3. *Prop.* 31; that is, retaining the Symbols used in the *Propositions* concerning the Motion of the Blood and the Discharges, M will be as F P, or as D^2L P, or as D^2V, or as Z. All this may be allowed, since it is very rational to think that the vibrating Motion of

the arterial System, and Quantity of Blood which flows through it in a given Time, are always proportional to each other.

Cor. 5. If the Quantity of Matter in the Fibre be as the Resistance given to its Motion, if the Square of its Diameter be as its Length, and the Time of an Extension be as its Strength; the Quantity of its vibrating Motion generated in a given Time, will be directly as the extending Force, and inversly as the Time of an Extension. If q be as R, d^2 as l, and t as S; M will be as $\frac{F}{t}$.

Cor. 6. If the Length of an Extension be as the extending Force, and the Square of the Diameter of the Fibre be as its Length, or the Diameter and Length be both given;

ven; the Time of an Extension will be as the Resistance and Strength of the Fibre, taken together. If E be as F, and d' as l, or d and l be both given; t will be as R S.

In the vibrating Motion of the System of Arteries in a living Animal, the Time of one Extension is the Time of one Pulse, and the Time of one Pulse is inversly as the Number of Pulses in a given Time; that is, t is as $\frac{1}{P}$: And therefore, if this *Corollary* obtains in the System of Arteries, the Number of Pulses in a given Time will be as the Resistance given to the Force of the Heart and Strength of the Fibres of the System, taken together inversly; that is, P will be as $\frac{1}{RS}$; or, the Pulse will be quickened by Things which lessen the Resistance and weaken the Fibres. Heat increases the Force of the Heart, makes

the

the Pulse greater and quicker, lessens the Resistance, and weakens the Fibres; all which Heat ought to do, to make this *Corollary* obtain in the Motion of the Blood of one and the same Body.

A greater Degree of Heat by increasing the Force of the Heart, and enlarging the Capacity of the System of Blood-vessels, will increase the Velocity of the Blood by *Prop.* 12. And that a bare Dilatation of the Blood-vessels by Heat, without an Increase of the Force of the Heart, will increase the Quantity of Blood which flows through one and the same Part of the System in a given Time, follows from *Prop.* 1; and may likewise be gathered from some Experiments made by Mr. *Hales*. For he found, "that a "given Quantity of warm Water, "impelled by its own Weight, "pass'd quicker through the same "Blood-

"Blood-veſſels than the ſame Quantity of cold Water; that on repeating the Experiments with each ſeveral times, the warm Water paſs'd ſtill quicker and the cold Water ſtill ſlower in each ſucceeding Trial; and that the warmer the Water was, the quicker it paſs'd; that common Brandy, and Decoctions of the *Peruvian* Bark, Chamomile Flowers, and Cinnamon, paſs'd all much ſlower than warm Water; and the Decoction of the *Peruvian* Bark ſlower than the reſt; and that they all paſſed ſtill ſlower in each ſucceeding Trial.

That a given Quantity of Fluid, impell'd by a given Force, ſhould paſs through the ſame Veſſels in a longer or a ſhorter Time, muſt be owing either to a Change in the Capacity of the Veſſels, or to a Difference in the Nature of the Fluid moved

 through

through them. A given Quantity of the same Fluid impelled by a given Force, will, from the Nature of the Motion of Fluids through Pipes, pass through the same Vessels in a less Time when they are wider than when they are narrower. And if the Capacity of the Vessels continue the same, a given Quantity of a different Fluid, impell'd by a given Force, will pass through them in a less or a greater Time, as the Fluid is less or more tenacious, or as the Attraction between it and the Side of the Vessel is weaker or stronger.

Cor. 7. If the Quantity of Matter and vibrating Motion of the Fibre be both given; the Length of one Extension will be as the Time in which it is made. If q and M be given, E will be as t.

To

To have the vibrating Motion of one and the ſame Syſtem of Arteries given, the Frequency of the Pulſe muſt be inverſly as its Magnitude, or the Pulſe muſt become quicker as it becomes leſs, and on the contrary. For in this Caſe, E expreſſes the Magnitude and t the Time of a Pulſe: But t is as $\frac{1}{P}$: And therefore, P is as $\frac{1}{E}$.

This Property of the Pulſe never obtains in a natural and healthful State of the Body, nor ever with Exactneſs in a diſeaſed State. And yet the Pulſe is always quickened on a great Diminution of its Magnitude, as will appear by the following Experiments and Obſervations.

Lower on bleeding Dogs to Death found, that after they had loſt much Blood, and began to grow faint, the Pulſe grew quicker, on the Veſſels growing empty, and the remaining

Blood not being sufficient to fill the Ventricles of the Heart; and that it grew quicker and smaller continually from the continual Loss of Blood, till the Motion of the Heart ceased for want of Blood to support it.

Mr. *Hales* on bleeding Horses to Death observed, that on tying the Horse to make the Experiment, the Pulse was quickened from 36 or 38 to above 60 Beats in a Minute; that as the Horse grew faint from the Loss of Blood, the Pulse grew still quicker, and beat above 100 times in a Minute before he expired, which happened after he had lost 16 or 17 Quarts of Blood; that when he came near the Time of expiring, he breathed quick, sigh'd deeply, struggled violently, and fell into cold clammy Sweats; that the projectil Force of the Heart, measured by the Height to which it threw the

Blood up a Tube faſtened to the Orifice, grew leſs and leſs, but irregularly on Account of the Sighs and Struggles which always increaſed it; and that this Force at the Time of expiring was not above a fourth Part of what it was at the Beginning.

I have ever obſerved the Pulſe to be quick, when it becomes very ſmall by great Loſſes of Blood. A Woman, from a very great Loſs of Blood from the *Uterus*, had a Pulſe extremely quick, but ſo very ſmall, that it could ſcarcely be felt, with great Faintneſs, Reſtleſſneſs, Sighing and Coldneſs of the Limbs; all which Symptoms vaniſhed in a little Time by Reſt and Nouriſhment.

The Pulſe is quick and ſmall in Bodies chill'd by cold Air, and in the cold Fit of an Ague, in malignant Fevers, moſt Convulſions, and a Coagulation of the Blood by Poiſons. Hence we learn, that an

Incrassation of the Blood and Contraction of the Blood-vessels, when they happen in any considerable Degree, make the Pulse quick and small: But an Incrassation of the Blood and Contraction of the Blood-vessels lessen the Motion of the Blood: And therefore, the Pulse becomes quick and small on a considerable Diminution of the Motion of the Blood. The Pulse is very quick and small, and the Motion of the Blood languid, in dying Persons. The Pulse was very quick, little and creeping, in a Man in whom the Valves of the Aorta were found ossified and stood half open. By this Fault in these Valves, part of the Blood which was thrown out of the Left Ventricle in each Systole, was forced back again into the Ventricle by the Contraction of the Aorta; which must first have given a Check to the Motion of the Blood through the Lungs,

Lungs, and thereby gradually to the Motion of the Blood through the whole Body; the Consequence of which was an *Asthma* and Dropsy, of which he died about the Age of 50. The Pulse is quick and small, when the Cavities of the Heart, or of the large Blood-vessels terminating in them, are much contracted by Polypuses, or by Compression. And it becomes very quick, small and trembling, on tying or cutting the principal Nerves of the Heart. *Galen* observed the Pulse to become quick and large under moderate Exercise, and a moderate Use of a warm Bath; but quick and small under much and violent Exercise, and an immoderate Use of a warm Bath; and he likewise observ'd it to be quick and small, when the vital Faculty (i.e. the Power which moves the Blood) is dissolved by want of Nourishment, the Malignity of Diseases, the

Violence of the Paſſions, the Violence or Continuance of Pain, and immoderate Evacuations. From theſe Obſervations it is evident, that the Pulſe becomes quick and ſmall on any great Diminution of the Blood's Motion, from whatever Cauſe that Diminution ariſes. The Quickening of the Pulſe on a great Diminution of the Blood's Motion, ſeems to be intended by Nature to raiſe the languid Motion, thereby to preſerve Life as long as is poſſible.

Proposition XLIII.

IN the vibrating Motion of an animal Fibre, if the Times of an Extenſion and Contraction be ſmall and equal, if the Lengths of an Extenſion and Contraction be ſmall, if a Reſiſtance

ſiſtance be given to the Contraction, and the contracting Force be equal to the Difference between the extending Force and the Reſiſtance; the Contraction in Proportion to the Extenſion, will be nearly equal to the Difference between the extending Force and Reſiſtance in Proportion to the extending Force; that is, $\frac{C}{E}$ *will be nearly equal to* $\frac{F-R}{F}$.

For ſmall Spaces deſcribed in equal Times are nearly as the moving Forces by which they are deſcribed, from the Nature of Motion: But by Suppoſition, an Extenſion and Contraction are ſmall, are deſcribed in equal Times by the extending and contracting Forces, and the contracting Force is equal to the Difference between the extending Force and the Reſiſtance: And therefore

therefore $\frac{C}{E}$ will be nearly equal to $\frac{F-R}{F}$.

Cor. 1. If the Resistance be nothing, the Contraction will be equal to the Extension. If R be 0, $\frac{F-R}{F}$ will be 1; and consequently, C will be equal to E.

When I made the Experiments from which I composed the Tables in *Prop.* 35, after I had taken the Extension caused by a Weight of 300 Grains in two Minutes, I removed all the extending Weight but 7 Grains, and let each Hair contract under that small Resistance during an equal Time. Upon comparing the Contractions with their respective Extensions, I found them to be nearly equal; only the Contraction in Proportion to the Extension, was a little less in the Hairs wet with

with ſtrengthening Fluids, than in the Hairs wet with weakening Fluids; it was leſs in the Hair wet with Oil-Olive than in the Hair wet with hot Water, in the Proportion of 8554 to 9875; and leſs in all the Hairs when dry, than in the Hair wet with hot Water, in the Proportion of 9400 to 9875. The Reſiſtance being 7 Grains and the extending Force 300, $\frac{F-R}{F}$ was 9766.

Cor. 2. If the Reſiſtance compared with the extending Force be of ſome Magnitude, the Contraction will be nearly as much leſs than the Extenſion, as the Difference between the extending Force and the Reſiſtance is leſs than the extending Force; C will be nearly as much leſs than E, as F—R is leſs than F.

The mean Extenſion of two dry Hairs, cauſed by a Weight of 300

Grains in two Minutes of Time, was $5\frac{1}{2}$; and their mean Contractions in an equal Time, under the Resistances of 100 and 200 Grains, was $3\frac{1}{2}$ and $1\frac{7}{8}$: Whence their mean Contractions in Proportion to their mean Extensions under those Resistances were 6363 and 3409.

The mean Extension of two Hairs wet with Oil-Olive, caused by the same Weight of 300 Grains in two Minutes, was $5\frac{13}{16}$; and their mean Contractions in an equal Time, under the same Resistances of 100 and 200 Grains, were $3\frac{1}{2}$ and $1\frac{15}{16}$: Whence their mean Contractions in Proportion to their mean Extensions under those Resistances, were 6021 and 3333.

The mean Extension of two Hairs wet with Water caused by the same Weight of 300 Grains in two Minutes (the mean Extension of which Hairs when dry was $5\frac{1}{2}$) was $55\frac{5}{32}$; and

and their mean Contractions in an equal Time, under the ſame Reſiſtances of 100 and 200 Grains, was $27\frac{21}{32}$ and 15: Whence their mean Contractions in Proportion to their mean Extenſions under thoſe Reſiſtances, were 5037 and 2732.

In all theſe three Caſes, $\frac{F-R}{F}$ was *6666* when the Reſiſtance was 100, and 3333 when the Reſiſtance was 200. So that this *Corollary* obtains nearly in dry Fibres, and Fibres wet with Oil; but does not obtain in Fibres wet with Water. For in Fibres wet with Water, $\frac{C}{E}$ is always conſiderably leſs than $\frac{F-R}{F}$.

For the ſame Reaſon that of Fibres of the ſame Strength when dry, thoſe which are dry or wet with Oil contract more in Proportion to their Extenſion, than thoſe which are wet with Water; I ſuppoſe it is, that of

Fibres of different Strengths when dry, thoſe which in that State are ſtronger will, when they are wet with Water and the Reſiſtance compared with the extending Force is conſiderable, contract more in Proportion to their Extenſion, than thoſe which are weaker; as will appear by the following Experiment.

When the extending Force was a Weight of 200 Grains, and the Reſiſtance a Weight of 160; the Contractions in Proportion to the Extenſions of three Hairs, whoſe Strengths when dry were as the Numbers 2285, 1951 and 1600, were 1465, 1392 and 1127 when the Hairs were wet with Water. In this Caſe, $\frac{F-R}{F}$ was 2000.

Cor. 3. If the Reſiſtance with reſpect to the extending Force be great, and both the Reſiſtance and the

the extending Force increaſe or decreaſe in the ſame Proportion; the Contraction will be nearly as the Extenſion. If $\frac{R}{F}$ be great, and R be as F, C will be nearly as E. For F being as R, $\frac{F}{R}$ and conſequently $\frac{F-R}{F}$ will be as 1; And therefore, C will be nearly as E.

When the extending Force was a Weight of 200 Grains, and the Reſiſtance a Weight of 160; the mean Contractions in Proportion to the mean Extenſions of Hairs, when dry, wet with Oil, and with Water, were 1719, 1411 and 1302.

When the extending Force was a Weight of 300 Grains, and the Reſiſtance a Weight of 240; the mean Contractions in Proportion to the mean Extenſions of the Hairs uſed in the laſt Experiment, when dry, wet

wet with Oil, and with Water, were 1909, 1601 and 663.

When the extending Force was a Weight of 400 Grains, and the Resistance a Weight of 320; the mean Contractions in Proportion to the mean Extensions of Hairs, which were of the same Strength when dry as those used in the two preceding Experiments, were 501, 596 and 464 when they were dry, wet with Oil, and with Water.

In each of these 3 Experiments $\frac{F-R}{F}$ was 2000.

By these Experiments when $\frac{R}{F}$ is great and given, F must have a certain Magnitude to make this *Corollary* obtain nearly even in dry Hairs.

Cor. 4. The Difference between the Extension and Contraction in Proportion to the Extension, is equal to the Resistance in Proportion to the

the extending Force; that is, $\frac{E-C}{E}$ is nearly equal to $\frac{R}{F}$.

If the Resistance be as the extending Force, the Difference between the Extension and Contraction will be nearly as the Extension by this *Corollary*; that is, if R be as F, E—C will be nearly as E; or in other Words, if $\frac{R}{F}$ be given, $\frac{E-C}{E}$ will be nearly given; as will appear by the following Experiments.

$\frac{E-C}{E}$ taken at a Medium from Hairs when dry, wet with Oil, and with Water, was 9531, 8588 and 8833, when the extending Force and Resistance were 200 and 160; was 8093, 8398 and 9263, when the extending Force and Resistance were 300 and 240; and was 9497, 9403 and 9535, when the extending Force and Resistance were 400 and

and 320. In all these Cases $\frac{R}{F}$ was 8000.

Cor. 5. If the Contraction be equal to the Extension, and the Resistance be of some Magnitude, the Force which causes the Extension will be nearly equal to the Difference between the extending Force and the Resistance, that is, nearly equal to F−R. For the Contraction and Extension being equal by Supposition, the contracting and extending Forces must be equal: But the contracting Force is nearly equal to F−R by the Experiments in the foregoing *Corollaries*: And therefore, the Force employ'd in causing the Extension will be nearly equal to F−R.

In the vibrating Motion of the Arterial System, if the Extension and Contraction be always equal, but

but of a different Magnitude at one Time from what they are of at another; the extending and contracting Forces will be always equal, but of a different Magnitude at those different Times: And consequently, by this *Corollary*, the Resistance given to the extending Force of the System will be always equal to the Resistance given to the contracting Force; that is, the Resistance given to the Force of the Heart which extends the Arteries, will be always equal to the Resistance given to the contracting Power of the Arteries. And this will obtain, whatever be the Nature of the Resistance, whether it arises from the Quantity or Tenacity of the Blood, from a Change made in the Capacity of the System, or from any other Cause.

PROPOSITION XLIV.

IF perfect Health in a human Body of a given Stature necessarily requires a certain and determinate Proportion of the Quantity of Blood to the Weight of the Body; then a grown Person who constantly enjoys good Health must always be nearly of the same Weight.

For it has been found by Observation, that animal Bodies have more Blood when lean than when fat, when lighter than when heavier; and by Consequence, a certain and determinate Proportion of the Quantity of Blood to the Weight of the same grown Body necessarily requires, that both the Quantity of Blood and Weight of the Body should be

be given: But by Supposition, perfect Health in a Body of a given Stature requires a certain and determinate Proportion of the Quantity of Blood to the Weight of the Body: And therefore, a grown Person who constantly enjoys good Health must always be nearly of the same Weight.

Proof by EXPERIMENTS.

Sanctorius found by Statical Experiments, "that Health is more "firm and lasting in a Body whose "Weight is neither increased nor "diminished in the Course of many "Years, than in a Body whose "Weight changes annually; that "Health will continue good even "to extream old Age, if Bodies be "always kept of the same Weight "in the four Seasons of the Year; "that Bodies whose Weights in the "Course of a Year are much in-

"creaſed and diminiſhed, are in "great Danger; that by how much "greater the Difference of Weight, "whether Increaſe or Diminution, "is in the Space of a Year, by ſo "much worſe is the Condition of "that Body; that Bodies have no "Diſeaſe in Autumn, if they be not "heavier in Autumn than in Sum-"mer; and that Bodies are not "troubled with any Diſeaſe in Au-"tumn, if they be clad warmly, "uſe Diureticks, and keep them-"ſelves of the ſame Weight as be-"fore." And that theſe Obſervations are true, I am fully ſatisfied from my own Experience in this Kingdom.

Cor. 1. The Food of a grown Body which is conſtantly in good Health, muſt always be nearly equal to its Diſcharges; otherwiſe, the Body

dy cannot always be nearly of the ſame Weight.

Cor. 2. An Equality between the Food and Diſcharges in a grown Perſon who conſtantly enjoys good Health, neceſſarily requires, that when there is an Increaſe or Diminution of the one, there ſhould be an equal Increaſe or Diminution of the other.

For Inſtance, when the Diſcharges are leſſened by Cold, Diſuſe of Exerciſe, or any other Cauſe, the Food muſt be equally leſſened; and when the Food is increaſed, the Diſcharges muſt be equally increaſed; otherwiſe, Perſons will be apt to fall into Diſeaſes. The Quantity of Food may be leſſen'd, either by taking leſs Food daily, or by faſting; and the Sum of the Diſcharges may be increaſed, either by uſing more Exerciſe, or by evacuating Medicines. Faſting is preferable

preferable to Evacuations caused by Medicines, because it does not raise that Irregularity and Disproportion in the Discharges, which are often produced by evacuating Medicines used frequently and for a long Time.

The Quantity of Food requisite to keep a grown Body in Health, ought to be such as gives no Uneasiness to the Body in concocting it, and can be carry'd off without any unusual or critical Discharge. *Sanctorius* found this to be true by Experiments, as appears from the following Aphorisms. " The most " healthful Quantity of Food for " every one is that, which can be " concocted without any Uneasi- " ness; as it will be, if as much as " is taken in be carried off by the " Discharges; which may be known " by weighing. The most health- " ful Quantity of Food is that, after " taking of which a Person can ap- " ply

" ply to Business with the same Ease
" as before. A Person may know
" how much he ought to eat, by
" finding himself for several Days
" together to return to the same
" Weight after Sleep without any
" Uneasiness. A Body is preser-
" ved in the same State of Health,
" when it returns to the same
" Weight without any unusual sen-
" sible Evacuation; but if it returns
" to the same Weight by a more
" than ordinary Discharge by U-
" rine or Stool, the Body begins to
" decline from a State of Health.
" And if a Body returns daily to the
" same Weight without any Change
" made in Perspiration, it will not
" want a Crisis, and be preserved
" in Health.

Cor. 3. A grown Person who is constantly to enjoy good Health, requires that the Force of the Heart

to the Weight of the Body ſhould be nearly the ſame at all Seaſons of the Year. For the Quantity of Blood is nearly as the Capacity of the Syſtem of Blood-veſſels, and the Capacity of the Syſtem of Blood-veſſels is as the Force of the Heart; but a grown Perſon who is conſtantly to enjoy good Health, at all Times requires a certain determinate Proportion of the Quantity of his Blood to the Weight of his Body; and therefore, he requires a certain determinate Proportion of the Force of his Heart to the Weight of his Body at all Seaſons of the Year.

I took the Weights of the Hearts and Bodies of ſeveral Animals, and upon comparing the Weight of the Heart with the Weight of the Body, found this Proportion to be greater in Men, Beaſts, and Birds, than in Fiſhes; in ſmall Birds and ſmall Animals

mals than in large ones, in younger Animals of the ſame Species than in older ones, and in Animals which uſe much Exerciſe than in Animals which are inactive.

The Strength, Activity, and Conſtitution of one and the ſame human Body in Health, do each of them depend upon the Magnitude of the Proportion of the Force of the Heart to the Weight of the Body. If this Proportion be great, the Body is ſtrong, active, and the Conſtitution ſanguin; and if the Proportion be ſmall, the Body is weak, inactive, and the Conſtitution fat or phlegmatick.

Cor. 4. A grown Perſon who conſtantly enjoys good Health, has nearly the ſame Quantity of Blood at all Seaſons of the Year.

Cor. 5. The Blood of a grown Person who constantly enjoys good Health, has nearly the same Motion, Tenacity, and Texture at all Seasons of the Year. For since the Force of the Heart and Capacity of the System of Blood-vessels of a grown Person who constantly enjoys good Health, are each nearly the same at all Seasons of the Year; the Motion of the Blood, which is regulated by the Force of the Heart and Capacity of the System of Blood-vessels, is nearly the same at all Seasons: But a given Motion of a given Quantity of Blood produced by a given Force, requires that the Blood should have a given Tenacity, and a given Tenacity requires that the component Parts of the Blood should each have the same Frame, and be in the same Proportion to the rest, that is, that the

the Blood ſhould have a given Texture. Therefore, this *Corollary* is true.

SCHOLIUM.

In this *Propoſition* I have proved, that the Weight of the Body, and the Quantity, Tenacity, Texture, and Motion of the Blood of a grown Perſon who always enjoys good Health, are each of them nearly the ſame at all Seaſons of the Year. And in this *Scholium*, I ſhall give ſome Account of the ſmall Changes which may happen in the Weight of the Body, and in the Quantity, Tenacity, Texture, and Motion of the Blood of a grown Perſon, who may notwithſtanding be ſaid to enjoy good Health; and alſo of the greater Changes in theſe Particulars which cauſe Diſeaſes.

First I shall give some Account of the small Changes which may happen in the Weight of the Body, and in the Quantity, Tenacity, Texture, and Motion of the Blood of a grown Person, who may notwithstanding be said to enjoy good Health.

Sanctorius informs us, "That "temperate Bodies are about three "Pounds (that is, near $2\frac{1}{2}$ *Averdupois* Pounds) lighter in Summer "than in Winter; that the Increase "of Weight is made in the Beginning of Autumn, and its Diminution in the Beginning of Summer; "and that external Cold, by driving the Heat to the Center, so "far strengthens Nature, as to enable it to bear two Pounds of retained perspirable Matter above "its usual Weight." And in this Country I have found, that grown Persons who live temperately are generally

nerally a little lighter in Summer than in Winter. The greateſt Difference of Weight which a grown Perſon can undergo without falling into Diſeaſes, I ſhall call the *healthful Latitude of Weight.*

The healthful Latitude of Weight of grown Bodies is greater in Winter than in Summer, in cold Countries than in hot Countries, and in Perſons of ſtrong Fibres than in Perſons of weak Fibres. For *Sanctorius* found, "That a Diminution "of Perſpiration, which in Sum-"mer can cauſe a malignant Fever, "can ſcarcely cauſe the leaſt Alte-"ration in Winter; that in a cold "wholſome Air Perſpiration is "check'd, the Pores are contract-"ed, but the Fibres are ſtrengthen-"ed, and the Weight of the re-"tained perſpirable Matter neither "hurts nor is perceived; and that "in a foul Air Perſpiration is

"check'd,

" check'd, the Pores are filled up " but not contracted, the Fibres " are relaxed not ſtrengthened, and " the Weight of the retained per- " ſpirable Matter both hurts and is " perceived:" But from theſe Obſervations, the Increaſe of Weight which can happen without cauſing Diſeaſes is greater in Winter than in Summer; and conſequently, greater in cold Countries than in hot Countries, and in Perſons of ſtrong Fibres than in Perſons of weak Fibres: And therefore, the healthful Latitude of Weight is greater in Winter than in Summer, in cold Countries than in hot Countries, and in Perſons of ſtrong Fibres than in Perſons of weak Fibres.

Perſons of ſtrong Fibres do not alter ſo faſt in their Weights by given Changes in the *Nonnaturals*, as Perſons of weak Fibres; or in other Words, the Change of Weight cauſed

sed by a Change of the Temperature of the Air, of Diet, Exercise, or any other of the Nonnaturals, is less in a given Time in Persons of strong Fibres than in Persons of weak Fibres. For by the foregoing Experiments, Changes made in the vibrating Motion of the Fibres by Resistances, and consequently by other Causes (suppose Changes in the Nonnaturals) are less in Persons of strong Fibres than in Persons of weak Fibres: But the vibrating Motion of the Fibres is proportional to the progressive Motion of the Fluids; and the progressive Motion of the Fluids regulates the Weight of the Body, which increases when the Motion of the Fluids lessens, and lessens when that increases: And therefore, the Change of Weight in a given Time caused by given Changes in the Nonnaturals is less, and consequently, slower in Persons of strong

Fibres than in Persons of weak Fibres.

No Change can happen in the Weight of the Body, but there must at the same Time a Change be made in the Quantity, Tenacity, Texture, and Motion of the Blood. For the Weight of the Body cannot be changed, but by a Change either in the Quantity of Food, or in the Sum of the Discharges; the Body will become heavier when its Food exceeds its Discharges, and lighter when its Discharges exceed its Food; and therefore, the Weight may be increased either by an Increase of the Quantity of Food, or a Diminution of the Sum of the Discharges: But the greatest Part of the Food passes into the Blood, and the two great Discharges, namely Perspiration and Urine, are Humours drawn off from the Blood; whence, no Change can be made in the Quantity

tity of Food or Sum of the Diſcharges, but there muſt at the ſame Time a Change be made in the Quantity of Blood; if the Food be increaſed, or the Diſcharges leſſened, the Quantity of Blood will always be increaſed at the Beginning of the Change, and leſſened afterwards if the Change continues till the Body grows fat or phlegmatick; for Bodies have always leſs Blood when they are fat or phlegmatick than when they are lean: And therefore, no Change can be made in the Weight of the Body, but at the ſame time a Change muſt be made in the Quantity of Blood. A Change in the Quantity of Blood will be attended with a Change in the Capacity of the Syſtem of Blood-veſſels, and that with a Change of Motion in the Blood; and a Change in that Motion will be attended with a Change in the Tenacity and Texture; becauſe the

Tenacity, Texture, and Motion of the Blood depend mutually on one another: And therefore, no Change can be made in the Weight of the Body, but there must at the same time a Change be made in the Quantity, Tenacity, Texture, and Motion of the Blood.

The Weight of a Person in Health, the Frequency of the Pulse, and specifick Gravity and Colour of the Urine, are all of them different at different Times of the natural Day. The Body is heavier after eating than before it, heavier after a plentiful Meal than after a spare one, and consequently, heavier after Dinner (which in these Kingdoms is generally the greatest Meal) than at any other Time of the natural Day. The Pulse is quicker after eating than before it, quicker after a plentiful Meal than after a spare one, and consequently, quicker after

Dinner than at any other Time of the natural Day, by *Tab. Exam.* 2. *Prop.* 15. The mean ſpecifick Gravities of the Urine of a healthful Man aged 56 Years, ſecerned from the Blood in the Night, Morning, and Afternoon, were 10300, 10292, and 10207; and the mean ſpecifick Gravities of the Urine of 25 healthful Boys, whoſe mean Age was 13½ Years, ſecerned from the Blood in thoſe Times, were 10221, 10220, and 10164. And the Night's Urine is generally of a deeper, and the firſt Urine after Dinner of a paler Colour, than the Urine made at any other Time of the natural Day. From theſe Experiments it appears, that an Increaſe of the Weight of the Body by Food is attended with an Increaſe of the Quickneſs of the Pulſe, and a Diminution of the ſpecifick Gravity

and of the Intenſeneſs of the Colour of the Urine.

The ſpecifick Gravity of the Night's Urine of a Perſon in good Health changes, as the Weight of the Body after Sleep is found to have changed; it increaſes when the Weight of the Body after Sleep is increaſed, and leſſens when that Weight is leſſened; as I found by taking my Weight, and the ſpecifick Gravity of my Night's Urine, every Morning for a whole Year; and then taking the Means of the Experiments of every Month. In the Month in which I was lighteſt, my Weight was 139 *Averdupois* Pounds, and the ſpecifick Gravity of my Urine was 10258; and in the Month in which I was heavieſt, my Weight was 142 and $2\frac{3}{4}$ Ounces, and the ſpecifick Gravity of my Urine was 10321. And in the

other

other Months, when the Weight of the Body increaſed or leſſened, the ſpecifick Gravity of the Urine increaſed or leſſened. The ſpecifick Gravity of the Night's Urine is leſs in Children than in grown Bodies, by the laſt Paragraph; and therefore, in growing Bodies the ſpecifick Gravity of the Urine increaſes with the Weight of the Body. The ſpecifick Gravity of the Night's Urine leſſens again, when Bodies grow old; for the mean ſpecifick Gravity of the Night's Urine of 12 old Men, whoſe mean Age was 63, was 10218, which is leſs than the mean ſpecifick Gravity of the Night's Urine of healthful Bodies of a middle Age, which I judge to be about 10300. Now if we ſuppoſe, what is generally true, that Bodies ſhrink in their Dimenſions, and leſſen in their Weights, when they come to be old; then it will be univerſally

true,

true, that the ſpecifick Gravity of the Night's Urine of healthful Bodies increaſes or decreaſes, when there is an Increaſe or Decreaſe of the Morning's Weight of the Body after Sleep.

The Quantity of ſaline and earthy Parts contained in a given Quantity of Blood, may be conjectured from the ſpecifick Gravity of its *Serum*. To form a Rule, whereby to judge of the Quantity of Salt and Earth contained in a given Quantity of Blood, I diſſolved different Quantities of ſeveral different Salts in a given Quantity of Water; *viz.* 1, 2, 4, and 6 Drachms of common Salt, Sal-gem, Nitre, Sal-armoniac, volatile Sal-armoniac, Alum, white Vitriol, and Salt of Tartar, in 4 *Troy* Ounces of Water; I took the ſpecifick Gravities of the ſeveral Solutions, and found the Exceſſes of the ſpecifick Gravities of the Solutions

lutions of each Salt above the ſpecifick Gravity of Water, to be nearly as the Quantities of Salt diſſolved. The Exceſſes of the ſpecifick Gravities of the four Solutions of Sal-armoniac above the ſpecifick Gravity of Water, were 104, 208, 398, 585, which were nearly as the Quantities of Salt diſſolved. The Exceſſes of the ſpecifick Gravities of the Solutions of common Salt above the ſpecifick Gravity of Water, were 209, 446, 866, 1154, which likewiſe were nearly as the Quantities of Salt diſſolved. And the ſame obtained nearly in the Solutions of each of the other Salts. Now if the Salt of the Blood be a Kind of Sal-armoniac, as is generally ſuppoſed, if S be put for the Exceſs of the ſpecifick Gravity of the *Serum* of the Blood above the ſpecifick Gravity of Water, if the Quantity of Salt and Earth contained in any

Quantity

Quantity of Blood be ever in a given Proportion to the Quantity of Salt and Earth contained in an equal Quantity of the *Serum* of that Blood, if the Exceſſes of the ſpecifick Gravities of the Blood and *Serum* in Bodies of a middle Age be 540 and 300, as they may be allow'd to be from Dr. *Jurin*'s Experiments, and if the Exceſſes of the ſpecifick Gravities of the Blood and its *Serum* be as the Sums of the Salt and Earth contained in equal Quantities of thoſe Fluids; then from the foregoing Experiments, .05S will be the Drachms of Salt and Earth contained in a *Troy* Pound of Blood. For Inſtance, if S be 300, a Pound of Blood will contain 15 Drachms of Salt and Earth.

In order to know how the Blood of Bodies of different Ages is ſaturated with Salt and Earth, I took the ſpecifick Gravities of the *Serum* of the

the Blood of five healthful old Men whoſe mean Age was 72 Years, and of ſix healthful Boys whoſe mean Age was 8 Years, and found their Means to be 10266 and 10277. From theſe Experiments, the Blood of old Bodies contains ſomething leſs Salt and Earth than the Blood of young Bodies, and both contain leſs than the Blood of Bodies of a middle Age, ſuppoſing the mean ſpecifick Gravity of the *Serum* of the Blood of Bodies of a middle Age to be 10300. The Quantities of Salt and Earth taken together in a Pound of the Blood of the old Men, the Boys, and Men of a middle Age, are in Drachms 13.3, 13.8, and 15.

The mean Proportions of the *Serum* of the Blood, ſeparated in 24 Hours, to the *Craſſamentum* of the ſix Boys and five old Men, were thoſe of 9187 and 6908 to 10000.

And the mean Proportion of the *Serum* to the *Crassamentum* of the Blood of Bodies of a middle Age, has been found to be that of 7143 to 10000. The *Crassamentum* of the Blood of old Bodies is much more tenacious (from a stronger Cohesion of its Parts) than the *Crassamentum* of the Blood of Children, as I have found by Observation.

From the small Difference there is in the Quantities of Salt and Earth in a given Quantity of Blood of old and young Bodies, and the great Difference there is in the Tenacities of their Blood, it is rational to think, that the different Tenacities of the Blood at different Ages depend chiefly on something different from Salt and Earth; which can be no other than Oil, which in itself is a tenacious Liquid, and gives a Tenacity to the Blood; in like manner as it gives a Tenacity to Water when it

it is dissolved in it by virtue of Salt; as we see in a Solution of Soap in Water, and in Mucilages. *See Schol. Prop.* 36.

The Urine of healthful Bodies is higher coloured in the Morning after Sleep, than at any other Time of the natural Day; it is higher coloured before eating than after it, and the Difference of Colour is greater after a plentiful Meal than after a spare one; it is higher coloured from much Exercise, Watching, Anger, Fasting, hot Meats, hot Air and hot Weather, than from their Contraries; it is higher coloured when the Blood abounds more with Bile than when it abounds less with it, as we learn from the *Jaundice*; it is higher coloured under a greater Degree of Heat in the Blood than under a less; and it is higher coloured in Men than in Women, and in Persons of a middle Age than in

Children and old Perſons. The ſpecifick Gravity of an exceedingly high coloured Urine was 10236, which is leſs than the ſpecifick Gravity of the Night's Urine of Bodies of a middle Age. Hence, the Colour of the Urine does not depend ſo much on Salt and Earth as on Oil, and probably depends on the Bile, which contains much Oil in its Compoſition. For, as I have obſerved, the Urine is very high coloured in a Jaundice, in which the Blood abounds much with Bile. The Blood abounds more with Bile, and the Urine is higher coloured, when the Degree of Heat in the Blood is greater than when it is leſs. And farther, by mixing different Quantities of Gall with plain Water, we may produce the ſeveral Colours which are ordinarily obſerved in Urine. One Part of the Gall of an Ox, mix'd with 15 or 16 Parts of Water, produced

duced the Colour of the Night's Urine of healthful Men of a middle Age. And the Colour of the Urine is ſometimes ſo intenſe, as to require one Part of Gall to two of Water to produce it.

Secondly, I ſhall give ſome Account of the greater Changes in the Weight of the Body, and in the Quantity, Tenacity, Texture, and Motion of the Blood, which cauſe Diſeaſes.

The Change of Weight which cauſes Diſeaſes, commonly exceeds the healthful Latitude of Weight; and conſequently, is greater in Winter than in Summer, in cold Countries than in hot Countries, and in Perſons of ſtrong Fibres than in Perſons of weak Fibres. The Weight of the Body is uſually increaſed at the Beginning of Fevers, and the moſt general Cauſes of Fevers are Cold, an Increaſe of Food,

or

or a Diminution of Exercise; all which are fitted to increase the Weight of the Body. But what the particular Increase of Weight is at the Beginning of different Fevers, in Persons of different Ages, Climates, and Constitutions, is not yet known for want of Experiments.

The Blood abounds more with Salt, Earth, and Oil, and is more tenacious at the Beginning of Fevers, than in a State of Health; as may be proved from the Experiments of *Tabor* and *Langrish*.

From the Experiments of *Tabor*, the specifick Gravities of feverish *Serum* are to the specifick Gravity of healthful *Serum*, as the Numbers 10363, 10381, 10399, or 10417 to 10308; or as the Numbers 10355, 10372, 10391, or 10409 to 10300, supposing 10300 to be the specifick Gravity of healthful *Serum* of the Blood of Bodies of

a

a middle Age. From theſe ſpecifick Gravities, the Drachms of Salt and Earth taken together contained in a *Troy* Pound of feveriſh and healthful Blood will, by the foregoing Rule, be nearly $17\frac{3}{4}$, $18\frac{1}{2}$, $19\frac{1}{2}$, or $26\frac{1}{2}$ and 15. From the Experiments I made on myſelf I gather, that the ſpecifick Weight of the *Serum* may increaſe from 10300 to 10321 without cauſing Diſeaſes; and therefore, the Quantity of Salt and Earth in a Pound of Blood of Bodies of a middle Age, may increaſe from 15 to 16 Drachms without cauſing Diſeaſes. The farther Increaſe from 16 till you come to $17\frac{3}{4}$, may only cauſe common Colds, or other ſlight Diſeaſes, but not be ſufficient to cauſe a Fever, at leaſt not one of any great Conſequence. *Tabor* gives an Account of a Fever of the pleuritick Kind, which was mortal to many of the common People of *England*,

England, in which the ſpecifick Gravity of the *Serum* was ordinarily between 10372 and 10391. The mean ſpecifick Gravity of the *Serum* of the Blood of ſeven Men in Fevers in this Kingdom, who all eſcaped, was 10358: And the mean ſpecifick Gravity of the *Serum* of one who died, was 10369; at the Beginning of the Fever the ſpecifick Gravity of his Urine, taken at a Medium from the 7th Day to the 11th, was 10295; it then ſunk to 10211, and continued in that State till he died, which was on the 12th.

From *Tabor*'s Experiments, the Proportion of the *Craſſamentum* of healthful Blood to the *Serum* ſeparated from it in 24 Hours, is that of 7 to 5, or of 1400 to 1000. And the Proportions of the *Coagulum* of a given Quantity of *Serum* to the Part evaporated by a gentle Heat in

24 Hours, in the mortal Fever before mentioned, in ordinary Fevers, and in Health, were those of 3000, 2333, and 1500 to 1000.

From the Experiments of *Langrish*, the mean Proportions of the *Crassamentum* of the Blood to the *Serum* separated in 24 Hours, in continual, quotidian, tertian, and quartan Fevers, were those of 3992, 3614, 3154, and 2424 to 1000; the mean Degrees of Cohesion, measured by a Weight just sufficient to separate the Parts of the *Crassamentum* of the Blood, in the said Fevers and in Health were, taking in the Weight of the Tube, as the Numbers 1603, 1275, 1152, 898, and 621; the Quantities of Salt, Oil, and Earth, obtained by Distillation from a given Quantity of Blood, were all greater in feverish Blood than in healthful Blood; and the Differences were much greater in

the Quantities of Salt and Oil, than in the Quantities of Earth; and the Urine which in the *Crisis* of a Fever deposited a large Sediment, contained a little less Water and Earth, but about three times more Salt, and near eight times more Oil, than were contained in an equal Quantity of healthful Urine.

From all these Experiments it appears, that the Blood abounds more with Salt, Earth, and Oil, and is more tenacious at the Beginning of Fevers, than in Health. Hence to cause a Fever, the Discharges of the Body must be more watry, or contain fewer saline, earthy, and oily Parts, for some little Time before the Fever commences, than they do in a State of Health; and therefore, the Things which cause Fevers must be such as render the Discharges more watry: But the Discharges are render'd more watry by taking Cold,

an Intermiſſion of Exerciſe, and an Increaſe of the Quantity of Food: And therefore, taking Cold, a ſudden Increaſe of the Food, and a ſudden Intermiſſion of Exerciſe, are the Cauſes of Fevers; as they are alſo found to be by Obſervation.

Proposition XLV.

If the Force which moves the whole Syſtem of Fluids in an animal Body be given; an Increaſe or Diminution of the Motion of the Fluids in any one Part of the Syſtem, will be attended with an equal Diminution or Increaſe of their Motion in other Parts of it; and the Diminution or Increaſe of Motion in the other Parts will be greater or leſſer, as they are nearer to or farther from that Part.

For the moving Force of the whole Syſtem of Fluids of an animal Body being given by Suppoſition, the Motion of the whole Syſtem generated by that Force in a given Time will be given: But a given Motion of the whole Syſtem neceſſarily requires, that an Increaſe or Diminution of Motion in any one Part of the Syſtem ſhould be attended with an equal Diminution or Increaſe of Motion in the other Parts of it; otherwiſe, the Motion of the whole Syſtem will not be given; and the Diminution or Increaſe of Motion in the other Parts will be greater or leſſer, as they are nearer to or farther from that Part, by *Prop.* 7. 19; And therefore, the *Propoſition* is true.

Cor. If this *Propoſition* be true, an Increaſe or Diminution of any one

one Discharge, or of the Motion of the Blood in any one Part of a human Body, will be attended with an equal Diminution or Increase of the other Discharges, or of the Motion of the Blood in the other Parts of the Body; and the Diminution or Increase of the other Discharges, or of the Motion of the Blood in the other Parts, will be greater or lesser, as the Discharges or Parts are nearer to or farther from that Discharge or Part.

We find by Observation, that in a *Diarrhæa*, Persons perspire little and make little Urine; that in a *Diabetes*, Persons perspire little and are costive; that Persons who *sweat* much, commonly discharge but little by Urine and Stool; that in a *Catarrh*, the Discharges by Perspiration, Urine, and Stool are commonly all lessened; that in a confirmed *Phthisis*, a large *Diarrhæa* lessens

lessens the Discharges by Sweat and Spitting, great *Sweats* lessen the Discharges by Stool and Spitting, and a great Discharge by *Spitting* lessens the Discharges by Sweat and Stool; that in the *Small Pox* and other *eruptive Fevers*, in which the Blood and Humours flow plentifully to the Skin, Persons are generally costive and make but little Urine; that in other *Fevers* an Increase of the Symptoms in one Part is generally attended with a Diminution of the Symptoms in other Parts; and that Perspiration compared with Urine, and consequently the Motion of the Blood at the Surface of the Body compared with its Motion in the inward Parts, is greater in Summer than in Winter, in hot Countries than in cold Countries. These Observations shew, that an Increase or Diminution of one Discharge, or of the Motion of the Blood in one Part

Part of the Body, is attended with a Diminution or Increaſe of other Diſcharges, or of the Motion of the Blood in other Parts of the Body.

Hippocrates has informed us, "That Gripes, a Weight in the "Knees, and Pain in the Loins, "require Purging; that a violent "Diſorder and Pain in the Head "ceaſe on the breaking forth of "*Pus*, Water, or Blood, at the "Noſe, Mouth, or Ears; that a "loathing of Food, Heart-burn, "Vertigo, and Bitterneſs in the "Mouth, in a Perſon who has not "a Fever, require vomiting; that "in Summer we ought rather to "vomit, and in Winter to purge; "that for Pains which require vo-"miting or purging, we ought to "vomit when the Pains are above "the Diaphragm, and to purge "when they are below it; that Hu-"mours which ought to be moved

" and discharged, must be moved
" towards and discharged by those
" Places to which they most tend,
" provided the Places be conveni-
" ent." By these Observations, when Evacuations are necessary to empty particular Parts, they ought to be made in convenient Places nearest to those Parts. Hence it is, that in an Apoplexy caused by too great a Quantity of Blood in the Brain, more speedy Relief is given by drawing Blood from the Neck, than from more remote Parts of the Body; and that in Inflammations, more speedy Relief is given by drawing Blood from Vessels which lie near them, than from Vessels lying at a Distance.

But though Parts loaded with Blood and Humours are more emptied by near Evacuations, than by distant ones of equal Quantities; yet, the Depletion by an Evacuation from

from a near Part is often not ſo laſting, and conſequently, not ſo ſerviceable, as the Depletion by an Evacution from a remote Part. For a near Evacuation gives a Tendency to the Blood and Humours towards the loaded Parts; which Tendency continuing after the Evacuation is over, makes the emptied Parts ſoon to fill again, unleſs the Diſcharge be very great: But an Evacuation from a remote Part gives a Tendency to the Blood and Humours towards that Part; which Tendency continuing after the Evacuation is over, cauſes a more plentiful Flow of Blood and Humours to that Part, and conſequently, a more ſparing Flow of them to the loaded Parts: And therefore, the Depletion, and conſequently, the Benefit ariſing from it, will not be ſo laſting from an Evacuation made in a near Part, as from an Evacuation made in a remote Part. Accordingly, *Tral-*

lian in the Cure of a *Hæmorrhage* from a Rupture of the Veſſels in the upper Parts, found much more Benefit from bleeding in the Ankle than in the Arm; and expreſly ſays, that a Sollicitation of the Humours to the remoter Parts makes a more laſting Revulſion. And it has been found by Experience, that drawing 8 or 9 Ounces of Blood from the *Hæmorrhoidal* Veins by Leeches, after bleeding in the Arm, is more prevalent in ſpitting or vomiting of Blood, or bleeding at the Noſe, than repeated Bleedings from the upper Parts: And that Pains in the upper Parts, particularly the Head and Side, are often more relieved by bleeding in the Foot than by bleeding in the Arm. So then to make a large and ſpeedy Depletion of the Veſſels, the Evacuation muſt be made as near the loaded Part as is poſſible; but to make the Benefit of ſuch Depletion

tion lasting, Recourse must be had to Evacuations from the remotest Parts.

Proposition XLVI. Problem VI.

THE Causes, Nature, aud Symptoms of Fevers being known; thence to determine the Methods of Cure.

The Causes of Fevers are either *remote* or *immediate*.

The common and ordinary *remote Causes* of Fevers, are *Cold*, *Excesses in Eating and Drinking*, an *Excess* or *Intermission of Exercise of Body or Mind*, and a *Suppression of some Discharge to which the Body has been accustomed*; all which, when great and sudden, are very apt to occasion Fevers.

The *immediate Cause of Fevers*, is the *Change* which is made in the *Tenacity* and *Texture* of the Blood

by the remote Causes. For all allow the immediate Cause of Fevers to be in the Blood: But a Change in the Blood must be a Change either in its Tenacity or Texture: And therefore, the immediate Cause of Fevers is the Change which is made in the Tenacity and Texture of the Blood by the remote Causes.

The *Tenacity* of the Blood, as far as yet appears from Experiments, is greater at the Beginning of Fevers than in Health, by *Schol. Prop.* 44. The same Thing may likewise be gathered from the Chilness and Coldness with which Fevers are introduced, and also from the Effects produced in the Blood by the remote Causes. For, cold Air, and an Intermission of Exercise of Body or Mind, will occasion a Diminution of the Heat of the Blood; and a Diminution of the Heat of the Blood will be attended with an Increase

crease of its Tenacity, by *Prop.* 41; an Exceſs of Exerciſe, by waſting the watry Part of the Blood, will leave the Blood more than ordinarily tenacious when the Body comes to cool; Exceſſes in eating and drinking will neceſſarily increaſe the Tenacity of the Blood if the Food be of a ſtrengthening Nature, as it commonly is when Fevers ariſe from Exceſſes in Diet; for of all Kinds of Food, Fleſh Meats and ſtrong Liquors are apteſt to produce Fevers; and the ſame Effect will follow from the Suppreſſion of a Diſcharge to which the Body has been accuſtomed, if the Suppreſſion be cauſed, as it uſually is, by Things of a ſtrengthening Nature, ſuch as Cold, Aſtringents, and the like.

The Blood, as to its *Texture*, abounds more with ſaline, earthy, and oily Parts, or, in other Words, its Quantity of theſe Parts in Pro-

portion

portion to its Quantity of Water, is greater at the Beginning of Fevers than in Health, by *Schol. Prop.* 44. And this likewise may be gathered from the Effects of the remote Causes of Fevers on the Discharges. Perspiration and Urine (the two great Discharges of the Body) are more watry, or abound less with saline, earthy, and oily Parts, when a Body is cold than when it is hot; and they are more watry under Excesses in eating and drinking than under a temperate Diet, from the Urine's being more watry after a full Meal than after a spare Meal, by *Schol. Prop.* 44; and from these Discharges being rendered more than ordinarily watry by Cold, and an Excess in eating and drinking, we may infer, that these two remote Causes of Fevers will overstock the Blood with saline, earthy, and oily Parts; for the fewer of these Parts the Dis-

charges

charges contain, the more muſt the Blood be ſaturated with them. An Intermiſſion of Exerciſe, by leſſening the Heat of the Blood, makes the Diſcharges more watry; and conſequently overſtocks the Blood with ſaline, earthy, and oily Parts. On the other Hand, an Exceſs of Exerciſe, by carrying off large Quantities of the watry Part of the Blood, will leave a more than ordinary Proportion of Salt, Earth, and Oil in the Remainder. And a ſudden Suppreſſion of a Diſcharge to which the Body has been accuſtomed, muſt have the ſame Effect in overſtocking the Blood with thoſe Parts, if the Matter of the Diſcharge abound with them. So that the common and ordinary remote Cauſes of Fevers do all of them foul the Blood, by making it to abound more with Salt, Earth, and Oil, than it does in Health. Hence Fevers may dif-

fer in their Natures, from Differences in the Tenacity and Foulneſs of the Blood.

The Weight of the Body is uſually increaſed at the Beginning of Fevers; and the Increaſe of Weight is greater in Winter than in Summer, in cold Countries than in hot Countries, and in Perſons of ſtrong Fibres than in Perſons of weak Fibres, by *Schol. Prop.* 44. The Increaſe of Weight in any Time, is always equal to the Exceſs of the Food above the Diſcharges in that Time; and therefore, the Increaſe of Weight at the Beginning of Fevers ariſes either from an Increaſe of the Food, or a Diminution of the Diſcharges, or from both. The Diſcharges are leſſened by ſudden Cold, a ſudden Intermiſſion of Exerciſe, or a ſudden Suppreſſion of an Evacuation to which the Body has been accuſtomed; and therefore, all the common remote

remote Cauſes of Fevers, excepting Exceſs of Exerciſe, are fitted to increaſe the Weight of the Body. If the Increaſe of Weight ariſe from an Increaſe of the Quantity of Fluids, as we may allow it to do from the remote Cauſes, it muſt ariſe from an Increaſe of the Quantity of Blood, or an Increaſe of the Quantity of Humours ſeparated from the Blood, or from both. It probably ariſes more from an Increaſe of Blood than of Humours, in ſanguin Bodies; and more from an Increaſe of Humours than of Blood, in Bodies which are fat or phlegmatick.

When the Blood by the remote Cauſes is rendered ſo tenacious and foul, as to require a Depuration; the Body grows chill and cold, and frequently ſhudders, as healthful Bodies do when they are greatly chilled by intenſely cold Air. During this State of the Body, the Pulſe is very

low and *quick*; and if a Vein be opened, the Blood flows out either by Drops, or ſo ſlow and cold as to coagulate as it falls. After the Coldneſs and Want of Motion in the Blood, a preternatural State as to Heat and Motion ſucceeds in it, which I call a *Fever*. If the Heat of the Blood be greater, and the Pulſe be greater and quicker, than they are in a natural and healthful State, I ſhall call the Fever a *high Fever*; and if the Heat of the Blood be leſs, and the Pulſe leſs and quicker, than they are in a healthful State, I ſhall call the Fever a *low Fever*.

A Fever is the great Inſtrument with which Nature depurates foul Blood, and reduces it to a natural State. This appears plainly from hence, that nothing makes tenacious Liquids, and conſequently tenacious Blood, ſo fluid as Heat; that nothing removes Obſtructions in the

the Blood-veſſels ſo ſoon and ſo effectually, as an increaſed Heat and Motion of the Blood; and that thoſe Fevers terminate ſooneſt by a *Criſis*, in which the Heat and Motion of the Blood are greateſt; and thoſe lateſt in which the Heat and Motion of the Blood are leaſt: Or in other Words, that the *higheſt Fevers* terminate ſooneſt by a *Criſis*, and the *loweſt Fevers* lateſt.

When the Matter which fouls the Blood, that is the febrile Matter, is rightly concocted by the Fever, Nature ſeparates it from the Blood, and diſcharges it out of the Body in a *ſalutary Criſis*. A *ſalutary Criſis* in Fevers is made by *Sweats*, *Urine*, *Hæmorrhages*, *Fluxes of the Belly*, and ſometimes by *Spitting*. High Fevers for the moſt part end by Sweats; and and in the End of all Fevers, by whatever Evacuation they terminate, the Recovery to perfect Health

 is

is by a natural Sweat. When the *Crisis* is made by *Sweat*, the Sweat is thin, warm, and profuſe; and the ſick Perſon is freed from the Fever by it; When it is made by *Urine*, the Urine is made firſt in a ſmall Quantity, and of a Straw Colour; but ſoon in a greater Quantity, with many Contents falling to the Bottom or ſwimming in it: When made by *Hæmorrhages*, the Flux of Blood may be great in Quantity, but is commonly of a ſhort Duration: When by a *Flux of the Belly*, the Flux is generally without Gripes, and commonly goes off in a Sweat: And when by *Spitting*, the Diſcharge is thin, *Aphthæ* ariſe which ſoon heal, and a Concoction appears in the Urine at the ſame Time. In the *Small Pox*, *Meaſles*, *Scarlet* and *Eryſipelatous Fevers*, the Blood is depurated by *Eruptions* and *Effloreſcences* in the Skin; in *Pleuriſies*, often by *Expectoration*;

ration; and in the *Plague* and *Pestilential Fevers*, frequently by *Swellings in the Glands*.

The Symptoms attending Fevers, and what those Symptoms portend, are best known from the *Aphorisms*, *Epidemicks*, and *Prognosticks* of *Hippocrates*, and a late learned Treatise upon them by a Physician in this Kingdom; to which I refer.

From this Account of Fevers, I now proceed to determine the *Methods of Cure*. From a Fever's being the great Instrument Nature uses to depurate foul Blood, it is evident, that what is called the Cure of a Fever, is only such a Regulation of it as makes it best answer that End. A just Regulation of a Fever consists in making such Evacuations, and directing such Diet and Medicines, as shall make the Fever depurate the Blood in the most perfect Manner. In appointing these Things, Regard must

must be had to the Age, and Habit of the Body; to the Nature, Symptoms, and Time of the Fever; and to the Distance of the *Crisis*.

From the *Increase of Weight*, we may infer the Usefulness of Evacuations in the Beginning of Fevers. The Body is emptied various Ways, namely, by *Fasting*, *Bleeding*, *Purging*, *Vomiting*, *Sweating*, and *Blistering*; all which I shall consider particularly, and shew which of them, under given Circumstances, will be most proper to lessen the increased Weight in the Beginning of Fevers.

Fasting lessens the Weight of the Body, not by causing any Evacuation, but from a Continuance of the Discharges during the Time of the Fast. I have known a Man in Health to lose near 4 Pounds of his Weight in 24 Hours, by wholly abstaining from Meat and Drink during that Time. From the Continuance of the

the Discharges during the Time of the Fast, we may gather that Fasting increases the Proportion of the *red Part* of the Blood to the *Serum*. Accordingly, this Proportion has been found very great in Persons who have died with Hunger. *Hippocrates* says, "that Fasting is to "be prescribed to Bodies which "have moist Flesh, for Fasting dries "Bodies." Bodies in Dropsies have sometimes been freed from their Load of Water, by wholly abstaining from Drink and living only upon dry Meat. Hence, Fasting is useful in the Beginning of Fevers in which the Increase of Weight is more from Humours than from Blood; and consequently, is more useful in phlegmatick Bodies, than in sanguin Bodies; in Winter, than in Summer; and in cold Countries, than in hot Countries. But tho' Fasting empties the Body, yet it does not

 appear,

appear, that it alters the Proportions of the Quantities and Motions of the Fluids through its ſeveral Parts: And therefore, when the Quantities and Motions of the Fluids are too great in ſome Parts, and too little in others; or, when they are more increaſed in ſome Parts than in others, as they frequently are in Fevers, we cannot hope to correct thoſe Irregularities by *Faſting*; but muſt have recourſe to ſome of the following Evacuations.

Bleeding leſſens the Weight of the Body, by leſſening the Quantity of Blood; and therefore, is uſeful in the Beginning of Fevers in which the Increaſe of Weight is more from Blood than from Humours; as we may ſuppoſe it to be in ſanguin Bodies, that is, in Bodies which have much Blood in Proportion to their Weights: But Bodies have more Blood when they are lean than when they

they are fat; and Bodies are generally leaner in Summer than in Winter, and in hot Countries than in cold Countries: And therefore, bleeding in the Beginning of Fevers is generally more useful in lean Bodies, in Summer, and hot Countries, than in fat Bodies, in Winter, and cold Countries. Accordingly, bleeding is more used, and with better Success, in *Italy*, *France*, and *Spain*, than in these and other Northern Kingdoms. Bleeding is useful in all Seasons and in all Climates, in the Beginning of Fevers attended with Inflammations; and much more so, when the Pulse is *hard*, as it is in Fevers attended with an Inflammation of the *Pleura*, and other membranous Parts. In these Fevers, when the Removal of the Inflammation is committed wholly to Bleeding, without any other Evacuation, large Quantities of Blood

must be drawn; and it must be taken, first from a convenient Part which lies nearest to the inflamed Part; and afterwards from a convenient Part which lies at the greatest Distance from it, by *Cor. Prop.* 45. Thus we find that in a true *Pleurisy*, or an *Inflammation* of the *Membranes of the Brain*, bleeding to the Quantity of 9 or 10 Ounces from the Foot, after bleeding largely from the Arm or Neck, gives greater Ease than repeated Bleedings from the upper Parts.

Purging lessens the Weight of the Body, by lessening the Quantity of Humours. The mean Loss of Weight of several grown Bodies, caused by a purging Medicine composed of a Drachm of *Jalap* and 10 Grains of *Calomel*, was about $2\frac{3}{4}$ *Averdupois* Pounds; and the mean Quantity of Liquor, drunk during the Time of purging, was about double

double the Loſs of Weight. And the Loſs of Weight cauſed by weaker Purges and *Clyſters* is proportionably leſs. Farther, Purging draws the Blood and Humours from the upper and outward Parts of the Body towards the lower and inward Parts, by *Prop.* 19. 45, and the following Obſervations. *Hippocrates* obſerved, "that it is good for a "Perſon who has an Inflammation "in his Eyes, to be ſeized with a "Flux of the Belly; that when a "*Diarrhœa* happens to a Woman "with Child, ſhe is in Danger of "miſcarrying; and that a Deafneſs "in Fevers is carried off by bleed-"ing at the Noſe, or ſpontaneous "Purging." And we find by Experience, that, after bleeding when neceſſary, moderately ſtrong Purges (compoſed of *Jalap* or *Pulvis Warwicenſis* and *Calomel*) are very effectual in removing Pains and Inflam-

mations in the *Eyes*, *Side*, *Head* and *Throat*, and in procuring the *Catamenia*; and that Perſons under a ſtrong *Diarrhæa*, or a *Diabetes*, diſcharge but little by Perſpiration: All which abundantly ſhew that Purging draws the Blood and Humours from the upper and outward Parts of the Body to the lower and inward Parts. *Hippocrates* likewiſe obſerved, "that a ſtrong *Diarrhæa* "coming on a *Leucophlegmatia*, "cures it." Whence I infer, that Purging is uſeful in the Beginning of Fevers, in which the Increaſe of Weight is more from Humours than from Blood; which is frequently the Caſe in cacheƈtick Bodies, in Winter, and in cold Countries. Purges, during the Time of their Operation, empty the lower Parts more than the upper Parts: But after the Operation is over, the lower Parts fill again; whence the Depletion

tion of the upper Parts becomes greater and more laſting, by *Cor. Prop.* 45.

Vomiting leſſens the Weight of the Body, partly by unloading the Stomach and its neighbouring Parts, and partly by increaſing Perſpiration; and therefore, is uſeful in the Beginning of Fevers, in which the Stomach is foul, and the neighbouring Parts are loaded with Humours from a Diminution of Perſpiration by Cold or other Cauſes. Farther, Vomiting turns the Blood and Humours from the lower and inward Parts of the Body to the upward and outward Parts; as may be gathered from the following Obſervations. *Hippocrates* has obſerved, "that a "ſpontaneous Vomiting coming "on a long Flux of the Belly, cures "it." And we find by Experience, that Vomiting is of great Service in checking a *Dyſentery*, an immoderate

rate Flux of the *Catamenia*, a Flux of Blood from the *Anus*, an *Hæmoptoe*, a *Diarrhæa*, a *Fluor albus*, and a *Gleet*; and that the Face and Eyes are commonly very red, and the Body frequently ſweats, during the Action of Vomiting: All which plainly ſhew, that Vomiting turns the Blood and Humours from the lower and inward Parts of the Body to the upper and outward Parts. Hence, the Effects of Vomiting and Purging, with regard to the Changes they make in the Motions of the Fluids in different Parts of the Body, are contrary to each other; Vomiting increaſes and Purging leſſens their Motion in the upper and outward Parts, and Vomiting leſſens and Purging increaſes their Motion in the lower and inward Parts. Repeated Purging brings down the *Catamenia*, by increaſing the Motion of the Blood through the *Womb*;

Womb; and Vomiting after other Evacuations, namely, Bleeding in ſanguin Bodies and Purging in cachectick Bodies, contributes much to remove the Inflammation in Pleuriſies, by increaſing the Motion of the Blood through the inflamed Part. It may be objected, that Vomiting in an *Hæmoptoe* will increaſe the Spitting of Blood; but this Objection is groundleſs: For I have rarely obſerved any Blood to be diſcharged during the Operation of a Vomit, and never any remarkable Quantity. Nor is there any Reaſon to apprehend, that Vomiting in an immoderate Flux of the *Catamenia* will increaſe it; ſince the Vomiting of Women with Child does not bring on that Diſcharge. Laſtly, Vomits, by the ſtrong Motion of the Muſcles which attends their Operation, attenuate tenacious Blood and increaſe its Motion;

tion; and are therefore useful on those Accounts, after other Evacuations, in the Beginning of Fevers attended with Inflammations and a small Motion of the Blood: Accordingly, I have frequently observed the Pulse to be raised by Vomits in low Fevers from a tenacious Blood.

Sweating lessens the Weight of the Body considerably. I have known a grown Person to have lost two Pounds in half an Hour, by sweating in a Chair contrived for that Purpose. This Evacuation is frequently of great Use in the Beginning of *Colds*, and slight Fevers; and also in high inflammatory Fevers in young Bodies, which may often be taken off in a little Time, by keeping them in a constant gentle Sweat in Bed with the testaceous Powders given in cold Water. Grown Bodies may take a Drachm of the Powders in three or four Ounces of cold Water

Water every third or fourth Hour, and Children five or six Years old may take half the Quantity of the Powders in half the Quantity of Water. It is to be observed, that Persons thus treated ought to be bled and vomited before they begin the Use of the Powders. If this Method be used at the Beginning, it generally takes off the Fever with all its Symptoms in less than two natural Days; but seldom in less than three or four, if it be not used till the seventh or eighth Day of the Disease. Grown Bodies thus treated often begin to spit a Day or two after they begin the Use of the Powders, and continue spitting for some Days after the Fever has left them. This is a natural Method of treating high inflammatory Fevers, in which the Blood is rendered tenacious by Cold and too great a Quantity of the Acid of the Air. For the Heat of the

Body in Sweating will take off the preternatural Tenacity of the Blood, as far as it is caused by Cold; and the testaceous Powders, from their being of an alcalious Nature, will be proper to take it off as far as it depends on the Acid of the Air; and Sweating, both by emptying the Body, and turning the Humours to the Skin, will greatly contribute to take off Inflammations in the inward Parts. Sweating with acidulated Drinks, taken warm, and Cordials, is a proper Evacuation in the Beginning of Fevers in which the Salts of the Blood are rendered too volatile by Heat or Putrefaction; as we may suppose them to be in Child-bed, pestilential, and other putrid Fevers. For Sweating will carry off Part of the volatile Salts, and Acids will be proper to correct the Remainder. After a Vomit, I have known gentle and frequently repeat-

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ed Sweats, excited in Bed by ſmall Quantities of Liquors taken hot, of great Uſe in the Beginning of low Fevers attended with frequent and irregular Succeſſions of Cold and Heat for three or four of the firſt Days. These Fevers frequently happen in this Kingdom to Men of a middle Age, and by being neglected in the Beginning often prove mortal. Sweating, as it attenuates the Fluids and turns their Courſe to the Skin, and as it relaxes and weakens the Fibres, will be more uſeful in the Beginning of Fevers in Winter than in Summer, in cold Countries than in hot Countries, and in Perſons of ſtrong Fibres than in Perſons of weak Fibres.

Bliſtering leſſens the Weight of the Body but little, and therefore, is but of little Uſe to take off the Increaſe of Weight in the Beginning of Fevers. In the Progreſs of

Fevers, Bliſters ſometimes do Good, and ſometimes Hurt. In low Fevers in which the Blood is tenacious, Bliſters often do Good by increaſing the Fever, and leſſening the Tenacity of the Blood; which Effects they produce by the Pain, Heat, and Inflammation which they commonly raiſe in the Part to which they are apply'd, and by the volatile Salts which they communicate to the Blood. In this Caſe, they muſt be repeated as often as their Effect in the Blood ceaſes, till within a very little Time of the *Criſis*. In low Fevers in which the Blood is diſſolved, as we may reaſonably ſuppoſe it to be in Fevers attended with *purple Spots* and *Hæmorrhages*, Bliſters do Hurt by farther increaſing the Diſſolution and Acrimony of the Blood. Bliſters frequently hurt in high Fevers, and ſometimes cauſe Convulſions and Death, unleſs they be apply'd

ply'd at a considerable Distance from the Head, and Opiats be given at the same Time. And they oftener hurt in high Fevers, when apply'd at or very near the Time of the *Crisis*, than when apply'd at any other Time of the Fever. In high eruptive Fevers, particularly the Small-Pox, Blistering along with other Evacuations, just before or after the Appearance of the Eruption, sometimes checks or strikes in the Eruption; and instead thereof, throws out purple Spots, causes Convulsions and Death. And in other high Fevers, a Separation in the Urine at a proper Time (which is a Sign of Concoction and an approaching *Crisis*) often goes off on the Application of Blisters, and does not appear again in several Days, and sometimes not at all. This is agreeable to the Doctrine of *Hippocrates*, who directs, " In the Crisis of Fevers
" and

"and after a perfect *Crisis*, not to "move or make any Change either "by purging Medicines or other "Irritations, but to leave all to Na-"ture." As Fevers are generally leſs ardent, that is, lower, ſo Bliſters are generally more uſeful, in Winter and cold Countries, than in Summer and hot Countries. Bliſters apply'd to the Back, after Perſons have begun to ſpit in Inflammations of the Lungs and Pleura, I have known to do hurt by quieting the Cough, and ſtopping the Spitting; and thereby, increaſing the Difficulty of Breathing and Inflammation. Bliſters apply'd to the Back in Fevers often eaſe the Head more during the Time of their riſing, than Bliſters apply'd to the Thighs or Legs; but the Eaſe given to the Head is often more laſting from Bliſters apply'd to the Thighs or Legs, than from Bliſters apply'd to the Back.

I have known Bliſters to quiet a Vomiting, and leſſen a *Diarrhæa* in Fevers; and they are particularly ſerviceable in the Convulſions of low Fevers attended with much *pale Urine*, commonly called *nervous Fevers*. *Hippocrates* obſerved, "that "all Abſceſſes of the Legs are good "in Inflammations of the Lungs; "and that of two Pains which hap-"pen together, but not in the ſame "Part, the greater obſcures the "leſſer." Hence, the Relief may be greater, but not not ſo laſting, from a Bliſter applied near to a diſtreſſed Part, than from a Bliſter applied at a great Diſtance from it.

To what has been ſaid concerning Evacuations, may be added, that when ſuch Evacuations are made as ought to be made, Perſons bear them eaſily, and are relieved by them. This is the Rule whereby *Hippocrates* judged of the Uſeful-

neſs

neſs or Hurtfulneſs of Evacuations, whether made by Nature or Art; and it ought ever to be carefully attended to, not only in Fevers, but in all other Diſeaſes. We may farther add, that Evacuations ought generally to be made in the Beginning of Fevers, and to be finiſhed within three or four of the firſt Days: Excepting, that in Fevers in which the Head is much engaged, Clyſters may be uſed, to draw the Humours gently from the Head by giving them a Tendency to the lower Parts, till Signs of Concoction appear in the Urine; and that in high Fevers, attended with an Inflammation of ſome principal Part, Evacuations may be uſed, to prevent Suppuration, till the Inflammation is either totally removed, or greatly abated. This may ſuffice concerning Evacuations in Fevers. I now proceed to conſider the Diet and Medicines, which

which are proper in theſe Diſeaſes.

The Diet and Medicines muſt be ſuch, as are fit to regulate the preternatural Heat and Motion of the Blood, that is, the Fever; ſo as that it may perfectly depurate the Blood, and reſtore it to a healthful State. The Diet muſt be cooling, if the Fever be high; and warming, if the Fever be low. Diet is cooling, either as it is of a cooling Nature, or as it is taken actually cold; and it is warming, as it is of a warming Nature, or as it is taken actually hot. Gruels, Panada, plain Water, Barley-water, Ptiſan, Small-beer, and Whey, made with ſmall White-Wine, Cyder, Juice of Lemons, Juice of Oranges, Vinegar, or Buttermilk, are all of a cooling Nature; and Broths of Fleſh, Ale, Wine, and other ſtrong fermented Liquors, and Whey made with ſtrong fermented

Liquors, are all of a warming Nature. Any of the Things here mentioned which are of a cooling Nature, may become warming by being taken hot; and any of those which are of a warming Nature, may lose much of that Quality by being taken cold. For in low Fevers, plain Gruels and Barley-water taken hot increase the Heat and Motion of the Blood, that is, heighten the Fever more, than many Liquids of a warming Nature taken cold. Drinks become more cooling by being impregnated with *Acids*, or with *Nitre*; both of which are of a cooling Nature, and may be given in high Fevers till Signs of Concoction appear in the Urine; but no longer, lest by their cooling Quality they should hinder a perfect Concoction of the febrile Matter, and thereby retard, if not intirely prevent the *Crisis*. *Acids* and *Nitre* ought not to

to be given in low Fevers in which the Blood is tenacious: For, by their cooling and diuretick Quality, they will make the Fever ſtill lower, and the Blood ſtill more tenacious; the Conſequence of which will be, that there will be no *Criſis* during their Uſe; and the Want of a *Criſis*, and of a thorough Extermination of the febrile Matter by it, will make the Recovery to Health at beſt very ſlow and uncertain. In ſuch Fevers, volatile alcalious Salts and Spirits muſt be given to thin the Blood, and all Liquids muſt be taken hot to rarefy it and increaſe its Motion. But tho' Acids are hurtful in Fevers which are low from too great a Tenacity in the Blood, yet they are very uſeful in low Fevers in which the Blood is diſſolved and its Salts are rendered volatile, by Putrefaction; in which Fevers, all Liquids muſt be taken warm, in order to raiſe and keep up a gentle

Sweat. In these Fevers, Cordials composed of ardent Spirits and Acids must be used, to give Tenacity to the Blood and Strength to the Fibres.

If we suppose the Demand of Nature to be a just Measure of the Quality and Quantity of the Nourishment which are proper in Fevers, we may from the Demand collect the following Rules concerning Diet; namely, All solid Food ought to be rejected, and liquid Food only admitted in Fevers; because, in all Fevers there is an intire Aversion to solid Food, and a Demand only for Liquids. Cooling acidulated Drinks ought to be taken plentifully in high Fevers; because, there is a great Demand for such Drinks in those Fevers. Little Drink ought to be taken in low Fevers from a tenacious Blood; because, there is but little Demand for Drink in those Fevers; and what is taken,

ken, muſt be taken hot to increaſe the Fever. Nothing ought to be taken, when there is no Demand; as there ſeldom is in the very Beginning of Fevers, and in the Beginning of their Exacerbations and Paroxyſms, in which the Body is cold, and the Motion of the Blood very low. And Drink ought to be taken plentifully in all Fevers in which the Salts of the Blood are rendered volatile and alcalious by Heat or Putrefaction; becauſe, the Thirſt is great in ſuch Fevers, as it is even in Health after a Meal of Fiſh, whoſe Salts are of an alcalious Nature. But theſe Rules we find to be juſt by Experience. And therefore, from the Demand of Nature we may judge of the Diet which is proper in Fevers.

Hippocrates for Diet in Fevers, uſed Barley Gruel thicker or thinner, more or leſs nouriſhing, according to the Nature and Circumſtances of the

the Disease, Water sweetened with Honey and plain Water, a Mixture of Vinegar and Water either plain or sweetened with Honey, Vinegar sweetened with Honey, and Wines of various Kinds; of all which he has given an Account in his Treatise on Diet in acute Diseases. According to that great Man, "a moist "Diet is proper for all Persons in "Fevers. The Diet ought to be "thinnest when the Fever is at the "Height. Diet ought not to be "given in the Exacerbations or Pa-"roxysms of Fevers, because it "hurts. Diet ought to be thinnest "in the most acute Fevers, and less "thin as Fevers are less acute. In "Fevers which soon come to the "Height, the Diet must be thin "from the Beginning; but in Fe-"vers which come later to the "Height, the Diet must be thinner "at and a little before that Time,

"but

" but more nouriſhing before to en-
" able the ſick Perſon to hold out.
" In the Beginning, the Gruel muſt
" not be much, nor thick. Some
" muſt be taken every Day, to pre-
" vent an Emptineſs of the Veſſels;
" and once or twice a Day, accord-
" ing to the Cuſtom of eating in
" Health; only 'tis adviſeable after
" the firſt Day to give it twice a Day
" rather than once, even to thoſe
" who have accuſtomed themſelves
" to eat but once a Day in Health.
" Much Gruel muſt not be given,
" even when the Diſeaſe is of the
" moſt drying Nature; but before
" the ſupping of it, muſt be drunk
" Water ſweetened with Honey, or
" Wine, which ever ſhall be moſt
" convenient. When any right
" Diſcharge happens, as a right
" Expectoration in a Pleuriſy, the
" Quantity of Gruel muſt be in-
" creaſed, and that in Proportion to
" the

" the Discharge; for the more Bo-
" dies are then moistened, the
" quicker commonly will be the
" *Crisis*; and on the contrary. Nei-
" ther Gruel nor Drink ought to be
" given in Fevers, when the Feet are
" cold.

In Fevers attended with Inflammations, watry Fomentations and watry Cataplasms must be apply'd, where they conveniently can, to the inflamed Part; for they assist much in removing Inflammations, by attenuating the Blood and increasing the vibrating Motion of the Fibres. Accordingly, *Hippocrates* directed a Bladder filled with hot Water, or a large Sponge squeezed out of hot Water, to be apply'd to the Side affected in a Pleurisy.

Opiats, as they lessen the vibrating Motion of the Fibres, and the Motion of the Fluids consequent thereon, are useful in high Fevers in

in which the Heat of the Blood is too great for a juſt Concoction of the febrile Matter, and the Motion of the Blood too rapid for a compleat Separation of that Matter from the Blood; in all Evacuations which from their Violence endanger Life; in *Phrenſies* and *Deliriums* from too great a Motion of the Blood, which frequently happen before critical Eruptions in Fevers; in high Fevers attended with a *Catarrh*, or great *Watchfulneſs*; and in the *Small-Pox*, during the Time of *Suppuration*; for Reſt and Sleep greatly promote Suppuration. Where *Opiats* are required in Fevers, the Greatneſs of the Doſe and Frequency of repeating it may both be determined by the Effect which is intended to be produced by them; for if no Inconvenience ariſes on uſing Opiats, they may be given in ſuch Quantities, and

ſo often repeated, as ſhall be neceſſary to attain the End propoſed.

In *intermitting Fevers*, commonly called *Agues*, the Tenacity of the Blood is leſs than in continual Fevers, by *Schol. Prop.* 44. And the immediate Cauſe, that is, the Foulneſs of the Blood, is both leſs in Quantity and of a leſs fixed Nature in intermitting than in continual Fevers; as we may gather from the Shortneſs of the Paroxyſms of the former, when compared with the Length of the Period of the latter. For it is rational to ſuppoſe the febrile Matter to be leſs or more in Quantity, and of a Nature leſs or more fixed, as it requires a leſſer or a greater Time wherein to be concocted, ſeparated from the Blood, and thrown out of the Body in a *Criſis*. The Blood is depurated (tho' not perfectly) by the Paroxyſm of

an

an Ague, in commonly leſs than one whole natural Day; whereas, many Days are ordinarily required for its Depuration by a continual Fever. The Return of the Paroxyſms in intermitting Fevers ſhews, that, tho' the Fever terminates with each Paroxyſm, yet the Blood is not perfectly depurated by it; ſome Degree of Foulneſs ſtill remains in the Blood, which on account of its Smallneſs may not be ſufficient to continue the Fever, but yet may be ſufficient by Degrees to taint and foul the Blood again, ſo as to cauſe a new Paroxyſm. For, the leaſt Quantity of *variolous Pus*, introduced into the Blood of a Perſon in Health who has never had the *Small-Pox*, can ſo change the Texture of the Blood in the Compaſs of eight or ten Days, as to cauſe the ſame Diſeaſe: And in other Fevers, a ſmall Quantity of febrile Matter

 remain-

remaining in the Blood after an imperfect *Crisis* often occasions a Relapse or Return of the Fever. We learn from *Sanctorius*, that Bodies are heavier at the Beginning of intermitting Fevers than in Health; for he found by Experiments, that if the Increase of Weight which happens in Autumn exceeds the healthful Latitude of Weight, it causes tertian or other putrid Fevers. The Urine is pale in the Beginning of the Paroxysm, when the Body is cold; it becomes high coloured, when the Body is hot; and when the Paroxysm is over, it is reddish when made, and when cold lets fall a Brick-coloured Sediment; which Sediment always shews a Disease to be of the intermitting Kind. Of this Kind are remitting Fevers which are periodical in their Exacerbations, and out of them have a Brick-coloured Sediment in the Urine;

rine; and alſo *Colicks*, *Pleuriſies*, *Rheumatiſms*, or *Rheumatick Pains*, which are periodical and have this Urine. Intermitting Fevers, from Neglect or ill Treatment, often terminate in other Diſeaſes, a *Dropſy*, *Jaundice*, *&c.* when the Heat and Motion of the Blood become too languid to form a febrile Paroxyſm.

From the Increaſe of Weight, we may infer the Uſefulneſs of Evacuations in the Beginning of intermitting Fevers. And we may know what Kind of Evacuations are proper, by the Account which has been given of Evacuations. After proper Evacuations are made, and the Patient has had a ſufficient Number of Paroxyſms, a Stop may be put to the Fever by the *Peruvian Bark*; a ſmall Quantity of which will generally be ſufficient for this Purpoſe, if it be taken in large Doſes, and the Doſes be repeated at ſhort Intervals.

An Ounce, or at most two, will generally be sufficient in a grown Person. This Medicine strengthens the Fibres, and increases the Tenacity of the Blood, by *Prop.* 41. and its *Scholium*; And we may allow it to have a Power of lessening the Motion of the Blood, and contracting the Blood-vessels, by some Experiments made by Mr. *Hales*, of which I have given an Account in *Cor.* 6. *Prop.* 42. By these Effects it lessens the Frequency of the Pulse, checks or intirely stops feverish Effervescences in the Blood, makes foul and turbid Urine in Diseases to become clear and transparent, and is of great Efficacy, after proper Evacuations, in stopping *Hæmorrhages*, *Sweats*, and a *Diabetes*. Hence, the *Bark* is very improper, nay hurtful, in intermitting Fevers, till the Matter which fouls the Blood is so far concocted and thrown off by re-

peated Paroxyſms, that Nature with a proper Regimen is able to concoct and throw off the Remainder without the Aſſiſtance of a Fever. Accordingly, ſtopping intermitting Fevers by the *Bark* has always been found moſt effectual and ſafe, when ſome Paroxyſms have paſſed before it has been given. The ſtrengthening Quality of the *Bark* may be increaſed by mixing it with Things of a more ſtrengthening Nature than it ſelf, ſuch as Salt of Tartar, or Sal-armoniac; and by waſhing down the Mixture with ſome ſtrengthening Liquor, ſuch as Claret, *German* Spa-water, or a Cordial in which plain Spirit of Wine, or ſome compound Water of the Shops, makes a conſiderable Part of the Compoſition.

All that remains to be ſaid concerning Fevers is, to ſhew how to conduct the Patient after the Fever is

is over, till he gathers Strength and is restored to perfect Health. If the *Crisis* has been perfect, there will be no Occasion for Medicines; for both Strength and Health may be restored by a proper Diet. The Food ought at first to be chiefly liquid; for liquid Food, as it is more easily digested, and on that Account can be taken in a greater Quantity, will be fitter for a weakened Body, and sooner repair the Waste made by the Disease, than solid Food. It ought by Degrees to be more solid, in order to give Driness and Strength to the weakened Fibres. But if the *Crisis* has been imperfect, the Patient must be purged in order to carry off the Remains of the Disease; and afterwards, nourished in the same manner as if the *Crisis* had been perfect. If the Fever be carried off by Sweating with the testaceous Powders, in the Manner above mentioned,

mentioned, the fame Conduct muft be ufed as after an imperfect *Crifis*; to prevent a Return of the Fever either in its old Form, or in the Form of an Ague.

General SCHOLIUM.

From what has been delivered in this and the laft Section, we know, how to increafe or leffen the Strength of the Fibres, and Tenacity of the Fluids; how to increafe or leffen the vibrating Motion of the Fibres, and progreffive Motion of the Fluids confequent thereon; by what Evacuations the whole Body, or any particular Part, ought to be emptied when it happens to be overloaded; and what are the proper Methods of correcting Irregularities in the Difcharges, when it fhall be judged fafe to do it. A Difcharge inftituted by Nature, to take off a

Load or Fulneſs, or to free the Body from irritating and hurtful Humours, ought not to be check'd by ſtrengthening Medicines, or by turning the Courſe of the Fluids to other Parts of the Body; but be ſuffered to go on, and be promoted by large Dilution, or otherwiſe, if the Strength will allow, till the Ends of its Inſtitution are attained. After which, it often ſtops of itſelf, when the Diſcharge has been of no long Continuance; but if it ſhould not, it may be ſafely check'd by ſtrengthening the Fibres of the Part from which the Diſcharge is made, and turning the Courſe of the Fluids from that to other Parts of the Body at the ſame Time. The Strength of the Body in Diſeaſes is meaſured by the Force of the Heart, which Force may be judged of by the Motion of the Blood; and we know this Motion by the Magnitude

and Frequency of the Pulſe. We may judge of the Sharpneſs of irritating and hurtful Humours by the Pain which attends the Diſcharge. The remote Cauſes of chronical Diſeaſes are, long Errors in the Nonnaturals, acute Diſeaſes ill cured, a preternatural Weakneſs or ill Conformation of ſome particular Part, and a Taint in the Fluids and Solids either hereditary or acquired. Now, from a Knowledge of all theſe Particulars, the proper Methods of conducting chronical Diſeaſes, as far as they are to be relieved by Art, may be ſo eaſily deduced, that it may ſeem unneceſſary to deſcend to a particular Treatment of them.

FINIS.

and Frequency of the Pulse. We may judge of the Sharpness of irritating and hurtful Humours by the Pain which attends the Discharge. The remote Causes of chronical Diseases are, long Errors in the Nonnaturals, acute Diseases ill cured, a preternatural Weakness or ill Conformation of some particular Part, and a Taint in the Fluids and Solids either hereditary or acquired. Now, from a Knowledge of all these Particulars, the proper Methods of conducting chronical Diseases, as far as they are to be relieved by Art, may be so easily deduced, that it may seem unnecessary to descend to a particular Treatment of them.

FINIS.

A
LETTER
TO
Dr. *CHEYNE*,
CONTAINING
An Account of the Motion of Water through Orifices and Pipes;
And an ANSWER to
Dr. MORGAN's Remarks
ON
Dr. ROBINSON's Treatise
OF THE
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A LETTER TO Dr. *CHEYNE*, &c.

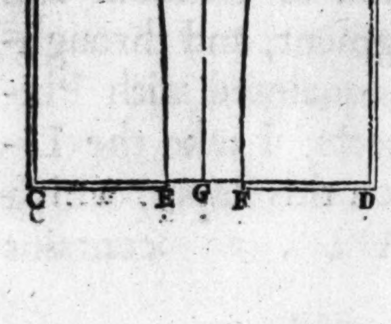
SIR,

KNOWING you to be a Perſon of Candour and Judgment, and throughly acquainted with Philoſophical Subjects, I take the Liberty to ſend you this Paper, which

contains an Account of the Motion of Water through Orifices and Pipes, and a Vindication of my Treatise of the *Animal Oeconomy* from certain Objections offered against it by Dr. *Morgan*, in his late Book, intitled, *The mechanical Practice of Physick.*

PROPOSITION I.

I*F* ACDB *be a cylindrical Vessel filled with Water,* AB *its upper Orifice,* CD *its Bottom parallel to the Horizon,* EF *a circular Hole in the middle of the Bottom,* GH *the Axis*



of the Cylinder perpendicular to the Horizon, GI *the Axis produced till* IH *becomes equal to the Space thro' which a heavy*

vy Body must descend in vacuo *to acquire a Velocity equal to the Velocity of the Water in the Surface* AB; *if* A *be put for the Area of the Surface of the Water* AB, a *for the Area of the Hole* EF, H *for* GH *the perpendicular Height of the Water in the Vessel above the Hole,* V *for the Velocity of the Water flowing through the Hole, and* v *for the Velocity of the Water in the Surface* AB; *and lastly, if the Vessel be supposed to be kept constantly full, by being supply'd at the Top as fast as the Water runs out through the Hole, and the Water descend from the Top of the Vessel to the Hole freely and without Resistance; I say that* V *will be equal to the Velocity acquired in falling* in vacuo *through the Space* $\frac{V^2 H}{V^2 - v^2}$, or $\frac{A^2 H}{A^2 - a^2}$, or $\frac{IG \times H}{IG - IH}$, or IG.

For

For IH being the Space through which a heavy Body muſt fall *in vacuo*, to acquire a Velocity equal to the Velocity of the Water in the Surface A B, and the Water being ſuppoſed to deſcend from the Surface to the Hole freely and without Reſiſtance, I G will be equal to the Space through which a heavy Body muſt fall *in vacuo* to acquire the Velocity of the Water in the Hole E F: But the Velocities acquired by a Body falling *in vacuo* through the Spaces I G and I H are in the ſubduplicate Ratio of thoſe Spaces, on Suppoſition that the Gravity of the Body is the ſame in I as in G, as it will be without any ſenſible Error if the Point I be but at a ſmall Diſtance from the Surface of the Earth; and the ſame Velocities V and v, are alſo as the Areas A and a, becauſe equal Quantities of Water paſs through the Surface A B and Hole

E F

EF in the ſame Time; and therefore $V . v :: A . a :: \sqrt{IG} . \sqrt{IH}$; and by Squaring, and Diviſion of Proportion, $\frac{V^2}{V^2-v^2}=\frac{A^2}{A^2-a^2}=\frac{IG}{IG-IH}=\frac{IG}{H}$, and, by multiplying by H, $\frac{V^2H}{V^2-v^2}=\frac{A^2H}{A^2-a^2}=\frac{IG\times H}{IG-IH}=\frac{IG\times H}{H}=IG$: And therefore V will be equal to the Velocity acquired by falling *in vacuo* through the Space $\frac{V^2H}{V^2-v^2}$, or $\frac{A^2H}{A^2-a^2}$, or $\frac{IG\times H}{IG-IH}$, or IG. Which was to be proved.

Cor. 1. H, the perpendicular Height of the Water in the Veſſel, is $=IG\times\frac{\overline{V^2-v^2}}{V^2}=IG\times\frac{\overline{A^2-a^2}}{A^2}$.

Cor. 2. V, the Velocity with which the Water flows through the

Hole,

Hole, is as $\sqrt{\frac{V^2 H}{V^2 - v^2}}$, or as $\sqrt{\frac{A^2 H}{A^2 - a^2}}$, or as $\sqrt{\frac{IG \times H}{IG - IH}}$, or as $\sqrt{IG}$.

Cor. 3. If a be equal to A, V will be nothing. For when a is equal to A, v will be equal to V by this *Propoſition*: But when a=A, and v=V, H will be nothing by *Cor.* 1. And conſequently V will be nothing by *Cor.* 2.

The Truth of this *Corollary* will appear likewiſe, by conſidering that when a is equal to A, I H will be equal to I G, and the Point H will coincide with the Point G: But when the Point H coincides with the Point G, the perpendicular Height of the Water in the Veſſel will be deſtroy'd, and when the perpendicular Height of the Water in the Veſſel is deſtroy'd, there can be

be no Velocity: And therefore when a=A, V will be nothing.

Farther, to ſuppoſe a to be equal to A, and conſequently v to be equal to V, will from the Nature of Gravity make V nothing. For Gravity accelerates the Motion of the Water from the Surface to the Hole, and makes the Velocity through the Hole greater than at the Surface, while there is the leaſt perpendicular Diſtance between them; and therefore to make the two Velocities equal, will be to deſtroy the perpendicular Height of the Water in the Veſſel: But when the perpendicular Height of the Water is deſtroy'd, there can be no Velocity: And therefore to ſuppoſe v to be equal to V, will be to make V nothing.

From all this it appears, that the Velocities v and V can never become equal, but in the Inſtant of their Evaneſcence on an infinite Di-

Diminution of the perpendicular Height of the Water in the Veſſel, and a conſequent Coincidence of the Points I and H with the Point G.

Cor. 4. If A be greater than A, H will be negative, and V will be affirmative. For when a is greater than A, $A^2 - a^2$ will be negative, and conſequently H will be negative by *Cor.* 1. And, when $A^2 - a^2$ and H are both negative, V, the Velocity with which the Water flows through the Hole, will be affirmative by *Cor.* 2.

A negative perpendicular Height of the Water in the Veſſel, and an affirmative Velocity neceſſarily require an Inverſion of the Veſſel, or turning of its Bottom upwards, by which Inverſion the Hole will become the upper Orifice and the upper Orifice become the Hole, a will

become

become A, and A will become a, v will become V, and V become v, and the Velocity will be affirmative, that is, the Water will move downwards, as it ought to do from the Nature of Gravity. That an Inverſion of the Veſſel is neceſſary, will appear farther by the following Argument. When a is greater than A, the Veſſel will be conical with its wider End downwards: But, from the Nature of Gravity, Water poured in at the Top or narrower End of ſuch a Veſſel, will deſcend in a cylindrical Column, which cannot fill the Baſe, as this *Propoſition* requires: And therefore there muſt be an Inverſion of the Veſſel, and ſuch a Change of Symbols as I have mentioned.

Cor. 5. If the Hole be exceeding ſmall in compariſon of the upper Orifice, the Velocity with which

the Water flows through the Hole, will, without any ſenſible Error, be equal to the Velocity which a heavy Body will acquire in falling *in vacuo* through a Space equal to the perpendicular Height of the Water in the Veſſel, that is, V will, without any ſenſible Error, be equal to the Velocity acquired in falling *in vacuo* through a Space equal to H. For when a is exceeding ſmall in compariſon of A, A^2-a^2 will be very nearly equal to A^2, and $\frac{A^2H}{A^2-a^2}$ will be very nearly equal to H: But, by this *Propoſition*, V is equal to the Velocity acquired in falling *in vacuo* through a Space equal to $\frac{A^2H}{A^2-a^2}$: And therefore V will be very nearly equal to the Velocity acquired in falling *in vacuo* through a Space equal to H.

Cor.

Cor. 6. The Force which can generate the whole Motion of the Water flowing out thro' the Hole, is equal to the Weight of a Cylinder of Water whose Base is the Hole, and whose Altitude is twice the Space through which a heavy Body must fall *in vacuo* to acquire the Velocity with which the Water flows through the Hole; that is, the Force is equal to the Weight of the Cylinder of Water $a \times 2$ I G. For the Time, in which the Water flowing out through the Hole becomes equal to the Cylinder of Water $a \times 2$ IG, is equal to the Time in which that Cylinder of Water in falling *in vacuo* by the constant Action of its own Weight will acquire a Velocity equal to that with which the Water flows out, that is, a Velocity equal to V; and from an Equality of the Times of the Motions, of the Quantities

tities of Matter moved, and of the Velocities, the Motions of the effluent Water and of the deſcending Cylinder will be equal: But when two Motions are equal, the Forces generating thoſe Motions are equal: And conſequently, the Force which can generate the whole Motion of the Water flowing out through the Hole, is equal to the Weight of a Cylinder of Water whoſe Magnitude is $a \times 2$ IG.

Scholium.

Since, by this *Propoſition*, the Velocity with which the Water flows through the Hole, is equal to the Velocity which a Body will acquire by falling *in vacuo* through a Space equal to $\frac{A^2 H}{A^2 - a^2}$, on Suppoſition that the Water deſcends down the Veſſel freely and without Reſiſtance; we may,

may, by knowing the Velocity acquired by a heavy Body in falling through ſuch a Space, find the Velocity with which the Water flows out through the Hole. For, according to Sir *Iſaac Newton*, a Body falling *in vacuo* near the Surface of the Earth will deſcribe $193\frac{1}{3}$ Inches or $16\frac{1}{9}$ Feet in one Second Minute of Time, and will have acquired a Velocity in the Time of the Fall, which being continued uniform would make it deſcribe twice that Space, that is $386\frac{2}{3}$ Inches or $32\frac{2}{9}$ Feet in one Second: But uniform Velocities are as the Spaces deſcribed by them in one Second, and the Velocities acquired in falling *in vacuo* through the Spaces $16\frac{1}{9}$ and $\frac{A^2H}{A^2-a^2}$ are in the ſubduplicate Ratio of thoſe Spaces: And therefore $32\frac{2}{9} . \surd 16\frac{1}{9} :: V . \surd\frac{A^2H}{A^2-a^2}$; whence V=

8.02773

$8.02773\sqrt{\frac{A^2H}{A^2-a^2}}$ Feet $= 96.33276$ $\sqrt{\frac{A^2H}{A^2-a^2}}$ Inches. This is the Velocity with which the Water flows through the Hole, ſetting aſide the Reſiſtance of the Air, and ſuppoſing the Water to deſcend down the Veſſel freely and without Reſiſtance.

The true Velocity with which the Water flows out through the Hole, will be had by applying the Quantity of Water diſcharged by Experiment, to the Area of the Hole and Time of the Diſcharge taken together; that is, putting Q for the Quantity of the Diſcharge in cubick Inches, D for the Diameter of the Hole in Inches or Parts of an Inch, and T for the Time of the Diſcharge in Seconds, by $\frac{Q}{.785381 6D^2T}$.

Now if the Water deſcend freely and without Reſiſtance, this Meaſure

ſure of the Velocity will be equal to the former, that is, $\frac{Q}{.7853816D^2T}$ $= 96.33276 \sqrt{\frac{A^2H}{A^2-a^2}}$; whence $Q = 75.65957 D^2T \sqrt{\frac{A^2H}{A^2-a^2}}$, and, putting W for the Weight of this Bulk of Water in Ounces *Troy*, $W = 39.93144 D^2T \sqrt{\frac{A^2H}{A^2-a^2}}$. But it has been found by Experiments, that the Bulk and Weight of Water diſcharged, always fall conſiderably ſhort of what they ought to be by theſe Rules; Sir *Iſaac Newton* found them to be leſs in the Proportion of 441 to 625, or of 1 to $\sqrt{2}$ nearly: And therefore Q and W muſt both be leſſened in this Proportion, and then we ſhall have $Q = 67.97239 \sqrt{\frac{A^2H}{A^2-a^2}}$, and $W = 53.38426 D^2T \sqrt{\frac{A^2H}{A^2-a^2}}$.

That leſs Water flows through the Hole in a given Time, than would flow through it if the Water deſcended down the Veſſel without any Reſiſtance, muſt be owing either to the Water's not filling the Hole when it paſſes through it, or to its paſſing through it with a leſs Velocity than that which is required in falling *in vacuo* through a Space equal to $\frac{A^2H}{A^2-a^2}$: But by carefully obſerving the Water as it flows out, I find that it fills the Hole if the Plate in which the Hole is made be very thin, and if the Plate be thick and the Hole be a ſhort Pipe, that it fills the inner Orifice of the Pipe which is contiguous to the Water in the Veſſel, though it does not fill the outer Orifice on account of the Contraction of the Vein, which Contraction extends from the inner Orifice of the Pipe, which is to be con-

conſidered as the Hole, to about the Diſtance of its Diameter: And therefore the Water paſſes through the Hole with a leſs Velocity than that which is acquired in falling *in vacuo* through a Space equal to $\frac{A^2H}{A^2-a^2}$. It paſſes through the Hole with a leſs Velocity, from its not deſcending freely and without Reſiſtance, and it does not deſcend freely and without Reſiſtance from its moving laterally as well as downwards throughout its Paſſage from the upper Orifice to the Hole. The lateral Motion of the Water, or the flowing together of its Parts from all Sides of the Veſſel throughout its whole Deſcent, gives a Reſiſtance to its Motion downwards, and that Reſiſtance leſſens the perpendicular Velocity, and makes the Quantity of Water diſcharged in a given Time leſs than it would be if there

was no ſuch lateral Motion, but the Water deſcended only perpendicularly from A B to E F.

The Velocity therefore with which the Water flows through the Hole, is equal to the Velocity which a heavy Body would acquire in falling *in vacuo* through a Space equal to one half of the Space $\frac{A^2H}{A^2-a^2}$. For the Velocity with which the Water flows through the Hole, is to the Velocity acquired in falling *in vacuo* through the Space $\frac{A^2H}{A^2-a^2}$ as 1 to $\sqrt{2}$, from Sir *Iſaac Newton's* Experiments: But from the Law of the Deſcent of heavy Bodies *in vacuo*, the Velocity acquired in falling through one half of the Space $\frac{A^2H}{A^2-a^2}$ is to the Velocity acquired in falling through the whole Space $\frac{A^2H}{A^2-a^2}$ as 1 to $\sqrt{2}$: And therefore the Velo-

city

city with which the Water flows thro' the Hole is equal to the Velocity acquired by falling *in vacuo* through one half of the Space $\frac{A^2 H}{A^2 - a^2}$.

The true Quantity of Water discharged will likewise be had by supposing the Velocity with which the Water flows through the Hole to be equal to that which a heavy Body will acquire in falling in *vacuo* through the Space $\frac{A^2 H}{A^2 - a^2}$, and the Hole to be contracted and its Area lessened in the Proportion of 441 to 625 or 1 to $\sqrt{2}$. For, since the Quantity of Water discharged is as the Velocity with which the Water flows through the Hole, the Area of the Hole, and Time of the Motion taken together, it is evident that the same Quantity of Water will be discharged in a given Time, whether the Velocity acquired in falling

falling *in vacuo* through the Space $\frac{A^2H}{A^2-a^2}$, or *a* the Area of the Hole, be leſſened in the Proportion of 1 to $\sqrt{2}$. Sir *Iſaac Newton* found the Area of a tranſverſe Section of the Vein at the Diſtance of about a Diameter from the Hole, to be leſs than the Area of the Hole in the ſaid Proportion. And in the Determination of this Motion he ſuppoſes the Hole to be contracted in that Proportion, and the Velocity, with which the Water flows through it, to be equal to the Velocity in the contracted Part of the Vein, that is, equal to the Velocity which a heavy Body will acquire in falling *in vacuo* through G I, or $\frac{A^2H}{A^2-a^2}$.

In order to know, whether the Velocities of Water flowing through circular Holes of different Diameters at the ſame perpendicular Diſtance

ſtance from the Surface of the Water, be all equal, and what Relation the Velocity of Water flowing through a Hole bears to the Velocity of Water flowing through a Pipe of an equal Diameter and at an equal perpendicular Diſtance from the Surface of the Water, I got Mr. *Stokes*, a skilful and accurate Mathematical Inſtrument-maker in this City, to make a very exact *Apparatus* for aſcertaining theſe Things by Experiments. And from the Experiments I compoſed the two following Tables.

The firſt Table contains, in the firſt Column the Time of the Diſcharge in Seconds, in the ſecond the perpendicular Heights of the Water above the Hole in *London* Feet, in the third the Diameters of the Holes in Parts of an Inch, in the fourth the Weights of Water diſcharged in Ounces *Troy*, and in the

TABLE I.				
T	H	D	V	$\frac{V}{D^2}$
5″	4	$\frac{2}{10}$	13.267	3317
		$\frac{4}{10}$	49.	3062
		$\frac{5}{10}$	76.	3040
		$\frac{8}{10}$	186.	2906
	2	$\frac{2}{10}$	9.	2250
		$\frac{4}{10}$	35.	2193
		$\frac{5}{10}$	54.	2160
		$\frac{8}{10}$	133.75	2090

the fifth the Velocities meaſured by the Weights of Water diſcharged apply'd to the Squares of the Diameters of the Holes.

By this Table, the Velocities of Water flowing through Holes of different Diameters, and at the ſame perpendicular Diſtance from the Surface of the Water, are all nearly equal; only the Velocity is ever ſome-

something greater through a smaller Hole than through a larger.

The second Table consists of three Parts, and each Part of three Columns. The first Column of each Part contains the Diameter of

TABLE II.

D	L	V	D	L	V	D	L	V
$\frac{2}{10}$	O	13.267	$\frac{4}{10}$	O	49.	$\frac{8}{10}$	O	186.
	D	14.985		D	57.		D	213.25
	2 D	15.		2 D	58.5		2 D	234.
	3 D	14.367		3 D	55.		3 D	226.5
	4 D	14.300		4 D	54.5		4 D	221.
	5 D	14.233		5 D	53.75		5 D	212.
	10 D	13.212		16 D	49.		16 D	196.
							23 D	186.

the Pipe in Parts of an Inch, the second the Lengths of the Pipes beginning from O, that is from an Hole, and the third the Velocities expressed by the Weights of Water discharged in five Seconds of Time. The Holes and Pipes were all at the

D Distance

Diſtance of 4 Feet from the Surface of the Water, and the Pipes lay all parallel to the Horizon.

By this Table, the Velocity increaſes from the Hole till the Length of the Pipe becomes equal to about twice its Diameter, that is, equal to about 2 D, and is greater there than at any other Length of the Pipe. The greateſt Velocities in theſe Pipes in Proportion to the Velocities through their reſpective Holes, which Holes may be conſidered as Pipes of infinitely ſmall Lengths, are as the Numbers 1130, 1215 and 1258, in Proportion to 1000: Whence we learn, that the greateſt Velocity in a Pipe in Proportion to the Velocity through an Hole of an equal Diameter and at an equal perpendicular Diſtance from the Surface of the Water, is ſomething greater in a wider Pipe than in a narrower one.

From

From the Length 2 D, the Velocity lessens continually on increasing the Length of the Pipe, and becomes equal to the Velocity thro' the Hole, when the Length of the Pipe becomes equal to 25.71478 $D\surd D$. For the Velocities through the Pipes were nearly equal to the Velocities through their respective Holes, when the Lengths of the Pipes were 10 D, 16 D, and 23 D, that is, 2, 6.4, and 18.4 Inches: But 2, 6.4, and 18.4, are nearly in the sesquiplicate Ratios of the Diameters $\frac{2}{10}$, $\frac{4}{10}$, and $\frac{8}{10}$: And therefore $18.4 . \frac{8}{10} \times \surd\frac{8}{10} :: L . D\surd D$; whence $L = 25.71478\, D\surd D$ nearly.

From five times that Length of a Pipe forward at which the Velocity is equal to the Velocity through an Hole of an equal Diameter, that is, from the Length 128.5739 $D\surd D$ forward, the Velocity will be measured nearly by the inverse subdupli-

cate Ratio of the Length of the Pipe; V will be nearly as $\frac{1}{\surd L}$. For, by the first Experiment, *Anim. Oecon.* p. 29, the Velocities in two Pipes, whose Lengths were 2 Feet and 8 Feet, and whose common Diameter was $\frac{345}{1000}$ Parts of an Inch, were nearly in the reciprocal subduplicate Ratios of the Lengths of the Pipes: But 128.5739 $D\surd D$ is nearly equal to 2 Feet, the Length of the shorter Pipe: And therefore from the Length 128.5739 $D\surd D$ forward, the Velocity will be measured nearly by the reciprocal subduplicate Ratio of the Length of the Pipe; V will be nearly as $\frac{1}{\surd L}$. Hence it follows, that from the Length 128.5739 $D\surd D$ forward, the Rectangle under the Velocity and square Root of the Length of the Pipe will be given; that is, $V\surd L$ will be given,

given, or be the ſame in Pipes of Lengths greater than 128.5739 $D\sqrt{D}$. It was nearly ſo in Pipes of half an Inch in Diameter, and of different Lengths from a Pipe of 4 Feet in Length to one of 100, when the perpendicular Height of the Water in the Veſſel was 3 Feet. From the Nature of the Motion of Water through Pipes, I think there muſt be a certain Length of a Pipe of a given Diameter beyond which $\frac{1}{\sqrt{L}}$ does not meaſure the Velocity; but what that Length is I cannot ſay for want of Experiments.

The Reaſon why this Meaſure of the Velocity does not begin to obtain till the Pipe be of a certain Length, may be this. The lateral Motion of the Water deſcending in the Veſſel, which Motion has been ſhewn to affect and diſturb the Motion of Water flowing through a Hole,

Hole, may likewiſe affect and diſturb its Motion through a Pipe, and hinder $\frac{1}{\sqrt{L}}$ from being an accurate Meaſure of the Velocity till the Pipe comes to be of ſuch a Length, that the Reſiſtance ariſing from the Weight of Water in the Pipe and from the internal Surface of the Pipe can in a good meaſure correct this Diſturbance; that is, till it comes to be of the Length 128.5739 $D\sqrt{D}$. And if this be the Reaſon why this Meaſure of the Velocity does not obtain with any Accuracy, till the Pipe comes to be of the Length 128.5739 $D\sqrt{D}$; then the Velocity with reſpect to $\frac{1}{\sqrt{L}}$ in Pipes exceeding this Length, will be always ſomething greater in a longer Pipe than in a ſhorter one (becauſe the Correction of the Diſturbance is greater in the former than in the latter)

latter) as I have always found it to be by Experiments.

This may ſuffice concerning the Motions of Water through Orifices and Pipes. I ſhall now proceed to Dr. *Morgan*'s REMARKS, and ſhall ſhew that they have all been occaſioned by his not having duly attended to what Sir *Iſaac* and I delivered concerning theſe Motions.

In p. 68. l. 4, 5. the Doctor ſays that F *will ever be as* D^2H, whereas had he attended to *Prop.* 36. *lib.* 2. *Newton.* he would have ſeen that F will never be as D^2H, but when the Area of the Hole is infinitely little in compariſon of the Area of the Surface of the Water in the Veſſel, and the Pipe lies parallel to the Horizon. For I have ſhewn from that *Propoſition*, that the Force which can generate the Motion of Water flowing through a Hole, is equal to the

the Weight of a Cylinder of Water whoſe Magnitude is $a \times IG$, or $a \times \frac{A^4H}{A^4-a^4}$: But this Force is evidently equal to the Force, which generates the Motion of Water flowing thro' a Pipe lying parallel to the Horizon, of an equal Diameter with the Hole, and inſerted into the inſide of the Veſſel at an equal perpendicular Diſtance from the Surface of the Water.

1. The Doctor ſuppoſes D and H to be given, and conſequently the moving Force, which is as D^2H, to be given; in which Caſe V will be meaſured by $\frac{1}{\sqrt{L}}$; and then affirms, *that if* L *be infinitely ſmall*, V *muſt be infinitely great, and if* L *be infinitely great*, V *will be infinitely ſmall.* Here I muſt acquaint this Author, that it by no means follows from L being infinitely ſmall, that

V muſt

V must be infinitely great, any more than it follows from a Body's being ing divisible *in infinitum*, that the Magnitude of that Body must be infinite. A finite Body will be infinitely great with respect to any of its Particles, when it is divided or supposed to be divided *in infinitum*; and a finite Velocity of Water flowing through a Hole, which may be considered as an infinitely short Pipe, will be infinitely great with respect to the Velocity of Water flowing through a Pipe infinitely long: And yet it is evident that neither the Body nor the Velocity through the Hole is infinite. Small and great, infinitely small and infinitely great, are Terms including a Comparison of Things with one another; thus a Thing is called small in comparison of a Thing of the same Kind which is great, and infinitely small in comparison of a

Thing which is infinitely great; a Hole is a Pipe of an infinitely ſmall Length, in compariſon of a Pipe infinitely long. And therefore, ſince V is as $\frac{1}{\surd L}$, the Velocity of Water flowing thro' an Hole will be infinitely greater than the Velocity of Water flowing thro' an infinitely long Pipe, tho' in reality the Velocity thro' the Hole be finite, and no greater than the Velocity acquired in falling *in vacuo* thro' $\frac{A^2H}{A^2-a^2}$.

2. The Doctor, p. 69, ſuppoſes D *to be given, and* H *to be proportional to* L; *in which Caſe the Velocity thro' the Pipe will be given.* However ſtrange and abſurd this may appear to this Gentleman, I can aſſure him I have found it to be true by Experiments. Two Pipes of the ſame Diameter, whoſe

Lengths were 8 Feet and 2 Feet, placed at the Diſtances of 4 Feet and 1 Foot from the Surface of the Water, diſcharged 97 and 83 *Troy* Ounces of Water in half a Minute. The Quantity diſcharged by the ſhorter Pipe was ſomething leſs than the Quantity diſcharged by the longer, which was owing to the Diſturbance ariſing from the lateral Motion of the Water deſcending in the Veſſel, which is ever greater in a ſhorter Pipe than in a longer, and at a leſs Diſtance from the Surface of the Water than at a greater.

3. In his third Conſequence, p. 70, drawn from V being as $\sqrt{\frac{DH}{L}}$, this Author ſuppoſes L *to be given, and* D *to be as* $\frac{1}{H}$; *in which Caſe the Velocity will be given.* He thinks this very abſurd, as I gather from his fifth Conſequence, in which he

ſays expreſly, *that* D *and* L *have nothing to do in the Matter, and cannot alter the Velocities at all.* But in this he is greatly miſtaken; for both the Diameter and Length of a Pipe affect the Motion of Water moving thro' it, and are neceſſarily to be taken into the Meaſure of the Velocity, as fully appears from the firſt and ſecond Experiments in the Proof of *Prop.* 1. *Anim. Oecon.* And I ſhall now ſhew by an Experiment, that the Velocity of Water flowing thro' a Pipe of a given Length is nearly the ſame, when the Diameter of the Pipe is inverſly as its perpendicular Diſtance from the Surface of the Water; that is, V will be given, when D is as $\frac{1}{H}$. Two Pipes, of the ſame Length, whoſe Diameters were 1 and 2, placed at the Diſtances of 2 and 1 from the Surface of the Water, diſcharged 68 and

29

20 Ounces of Water in half a Minute. The Velocities from these Discharges were as the Numbers 17 and 20. The first Velocity was something less than the second; because the first Pipe was wider and nearer to the Surface of the Water than the second, and consequently the Disturbance given to the Motion thro' the first, was greater than the Disturbance given to the Motion thro' the second.

4. In his fourth Consequence, p. 70, he supposes H *and* L *to be given; in which Case the Velocity will be as* $\sqrt{D}$. However absurd this Consequence may appear to the Doctor, I have proved it true by the second Experiment in the Proof of *Prop.* 1. *Anim. Oecon.* to which I refer him.

5. In his fifth and last Consequence, p. 70, he supposes D *and* L *to be given; in which Case* V *will be as* $\sqrt{H}$. This he allows to be true,

true, and ſays *it is the true Law of accelerating Gravity and Preſſure as determined by* Newton. But in this he is miſtaken. For V is not as $\surd H$ according to *Newton*, but as $\surd\frac{A^2H}{A^2-a^2}$, by *Cor.* 2. of the foregoing *Propoſition.*

The Doctor proceeds to ſhew the Abſurdity of what I aſſerted in my *Animal Oeconomy* from Sir *Iſaac Newton*, and have demonſtrated in the foregoing *Propoſition*, namely, that the Velocity of Water flowing thro' a Hole is equal to the Velocity acquired by a heavy Body in falling *in vacuo* through the Space $\frac{A^2H}{A^2-a^2}$.

1. *If this be the Space*, p. 71, 72, *through which a heavy Body muſt fall* in vacuo *to acquire a Velocity equal to the Velocity with which the Water flows through the Hole, then* V *will be as* $\surd\frac{A^2H}{A^2-a^2}$. *Now upon this*

this Supposition, let the differential Quantity $A^2 - a^2$ *be infinitely small, or let* a *be only not equal to* A, *and then the Expression* $\frac{A^2 H}{A^2 - a^2}$ *will be infinitely great; and consequently the Space described, as well as the Velocity acquired, will be infinite, where the perpendicular Pressure or Height of the Fluid is only finite and given; or which is the same thing, the Spaces described and the Velocities acquired, will be finite and infinite at the same Time and from the same Causes.* Here again the Doctor is greatly mistaken. For by the third *Corollary* of the preceding *Proposition*, (which *Proposition* is a plain and obvious Consequence of *Prop. 36. lib. 2. Newton.*) when a is equal to A, the Space described and Velocity are so far from being infinite, that both will be nothing. His Mistake here arose from his not knowing that when a

is

is equal to A, H will be nothing, by *Cor.* 1.

2. The Doctor goes on to ſhew the Abſurdity of my Aſſertion in the following Words, p. 72. *Let the differential* $A^2 - a^2$ *be infinitely ſmall but negative, and then the Expreſſion* $\frac{A^2 H}{A^2 - a^2}$ *will be negative, but infinite ſtill; the Conſequence of which muſt be, that the Fluid in this Caſe cannot deſcend and flow thro' the Orifice* a *at all; but on the contrary muſt aſcend perpendicularly, and flow upwards with an infinite Velocity, in a Direction quite contrary to that of Gravity.* Here likewiſe the Doctor is miſtaken. For when a is greater than A, H will be negative, and V affirmative, by *Cor.* 4. And when H is negative the Veſſel muſt be inverted, or turned with its Bottom upwards, which being done this Objection will vaniſh, by *Cor.* 4.

Having

Having ſhewn the Weakneſs of the Doctor's *Remarks* on my firſt *Propoſition*, I ſhall beg leave, before I anſwer his *Remarks* on my 24th *Propoſition*, to give a Demonſtration of the Law of the Blood's Motion, exhibited in *Prop.* 12, independent of my firſt Section concerning the Motion of Fluids thro' cylindrical Pipes; becauſe this Author ſeems to think, that all the mathematical Part of my Book depends on the Truth of that Section.

PROPOSITION II.

IF two healthful and perfectly well-proportion'd Bodies be ſituated alike with reſpect to the Horizon, if their Hearts be free from the Influences of all diſturbing Cauſes, and the Capacities of the two correſponding Ventricles

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tricles be proportional to the Capacities of the two whole Systems of Blood-vessels or of any two corresponding Blood-vessels, and if the Numbers of their Pulses in a given Time be inversly as the Times of two Systoles of their Hearts; the Velocities of their Blood in two corresponding Blood-vessels will be in the subduplicate Ratio of the Diameters of the Vessels, that is, putting V, v *for the Velocities, and* D, d *for the Diameters of the Vessels,* $V . v :: \sqrt{D} . \sqrt{d}$.

For the Velocities in any two Blood-vessels, and consequently in two corresponding Blood-vessels, of the two Bodies, are as the Quantities of Blood which flow into those Vessels in two Systoles of their Hearts, apply'd to the Squares of the Diameters of the Vessels and the Times of the two Systoles taken together; and the Quantities of Blood which

which flow into the Veſſels in two Syſtoles, are as the Capacities of the correſponding Ventricles of the Hearts, becauſe the Hearts are ſuppoſed to be free from the Influences of all diſturbing Cauſes, and the Bodies to be ſituated alike with reſpect to the Horizon; and therefore, putting L, l for the Lengths of two correſponding Blood-veſſels, or for the Lengths of the two Bodies, to which the Lengths of correſponding Blood-veſſels are ever proportional in perfectly well-proportion'd Bodies, and T, t for the Times of two Syſtoles, we ſhall have $V . v :: \frac{D^2L}{D^2T} . \frac{d^2l}{d^2t} :: \frac{L}{T} . \frac{l}{t}$: But by Suppoſition $P . p :: \frac{1}{T} . \frac{1}{t}$: And therefore $V . v :: LP . lp$.

By obſerving the Pulſes of healthful Bodies of different Lengths in the Morning when they were ſit-

ting, I have found that the mean Numbers of Pulſes in a Minute of Bodies of any two different Lengths, each Mean being taken from the Pulſes of a Number of Bodies of each Length, are very nearly as $\frac{1}{L^{\frac{3}{4}}}$ and $\frac{1}{l^{\frac{3}{4}}}$: But the mean Numbers of Pulſes in a Minute of Bodies of thoſe two Lengths, are the true Pulſes of two healthful and perfectly well-proportion'd Bodies: And therefore $P \, . \, p :: \frac{1}{L^{\frac{3}{4}}} \, . \, \frac{1}{l^{\frac{3}{4}}}$.

And by comparing the Diameters of the Aorta of Bodies of different Lengths with the Lengths of the Bodies, as far as I can judge from the few Experiments I made, the Diameters are nearly in the ſubduplicate Ratios of the Lengths: But the mean Diameters of the Aorta of Bodies of two different Lengths, each Mean being taken from the

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Diameters of this Veſſel of a Number of Bodies of each Length, are the true Diameters of the Aorta of two healthful and perfectly well-proportion'd Bodies of thoſe Lengths: And therefore $D . d :: \sqrt{L} . \sqrt{l}$, and $\sqrt{D} . \sqrt{d} :: L^{\frac{1}{4}} . l^{\frac{1}{4}}$.

And therefore in the Analogy $V . v :: LP . lp$, if inſtead of P and p, be ſubſtituted the Quantities $\frac{1}{L^{\frac{3}{4}}}$ and $\frac{1}{l^{\frac{3}{4}}}$ proportional to them, we ſhall have $V . v :: L^{\frac{1}{4}} . l^{\frac{1}{4}}$; and ſince $L^{\frac{1}{4}} . l^{\frac{1}{4}} :: \sqrt{D} . \sqrt{d}$, we ſhall have $V . v :: \sqrt{D} . \sqrt{d}$. Which was to be proved.

This *Propoſition* may be expreſs'd generally, by ſuppoſing $P . p :: \frac{1}{L^{m}} . \frac{1}{l^{m}}$, and $D . d :: L^{n} . l^{n}$. For then $V . v :: L^{1-m} . l^{1-m} :: D^{\frac{1-m}{n}} . d^{\frac{1-m}{n}}$. Hence, if hereafter it ſhall be

be found by a larger Experience, that the Meaſures of the Pulſes and Diameters of correſponding Blood-veſſels are different from thoſe aſſigned in this *Propoſition*, the Proportions of the Velocities in healthful and perfectly well-proportion'd Bodies of different Lengths, may be known.

For Inſtance, if it ſhall be found that m inſtead of being equal to $\frac{3}{4}$ is equal to $\frac{1}{2}$, and that n is $\frac{1}{2}$ as I have made it; then $V . v :: \surd L . \surd l :: D . d$. And if it ſhall be found, that m is $\frac{4}{5}$ and n $\frac{1}{2}$, then $V . v :: L^{\frac{1}{5}} . l^{\frac{1}{5}} :: D^{\frac{2}{5}} . d^{\frac{2}{5}}$. The Proportions of the Pulſes and Diameters of correſponding Blood-veſſels delivered from Experiments in this *Propoſition*, are, as far as I can judge, intirely agreeable to the Phænomena, and therefore I ſhall retain them till a larger Experience ſhall ſhew that they are not

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the Proportions which obtain in Nature.

I now come to consider the Doctor's Remarks on my 24th *Proposition*, which *Proposition* stands thus.

T*HE Life of Animals is preserved by acid Parts of the Air mixing with the Blood in the Lungs; which Parts dissolve or attenuate the Blood, and preserve its Heat, and by both these keep up the Motion of the Heart.*

I proved this *Proposition* from a Series of Experiments taken from Sir *Isaac Newton*, Dr. *Hook*, Dr. *Lower*, and others. And the Manner in which I proved it was this.

From Experiments I proved *first*, that a constant Supply of fresh Air is necessary to preserve the Life of Animals; *secondly*, that fresh Air preserves Life in Animals by the very

ſame Power, or by the Operation of the very ſame Parts, whereby it preſerves Fire and Flame in ſulphureous and unctuous Subſtances when once they are kindled; and *thirdly*, that Air preſerves Fire and Flame in ſulphureous and unctuous Subſtances when once they are kindled, and conſequently the Life of Animals, by its acid Particles. Had this Author attended to the Experiments from which I proved the ſecond and third Particulars, he could not but have ſeen that they were juſtly proved. For, ſince Animals die in Air rendered effete by burning Coals or Candles in it till they are extinguiſhed, and glowing Coals or Candles are extinguiſhed in Air rendered effete by Animals breathing in it till they die; it clearly follows, that Air preſerves Fire and Flame, and the Life of Animals, by the ſame Power, or by the Operation of the

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ſame Parts: And, ſince Fire and Flame can be produced without Air by mixing compound Spirit of Nitre, which is an Acid, in a certain Proportion with ſome Oils *in vacuo*, and can be preſerved without Air in a Mixture of common Sulphur and Nitre powdered when once it is kindled, it follows that Air preſerves Fire and Flame in ſulphureous and unctuous Subſtances when once they are kindled, and the Life of Animals, by means of its acid Particles. There is no way of proving this Inference to be falſe, but by proving that there are no acid Particles in the Air. But the Air abounds with ſuch Particles, as appears from the Nitre, which is found ſticking to the Sides of plaiſtered Walls, and to the Mortar between the Bricks of Brick Walls, which are defended from the Rain which would diſſolve it, and from

the Sun which would rarefy it and cauſe it to be exhaled into the Air. For Sir *Iſaac Newton* has proved from Experiments, that Salts are compoſed of Acid and Earth united by Attraction: Whence it follows, that the Formation of Nitre on the Sides of plaiſtered Walls and on the Mortar of Brick Walls defended from Rain and Sun, muſt be owing to acid Parts of the Air uniting with the earthy aſcalious Parts of the Lime, by the ſtrong Attraction which intercedes them: And therefore the Air abounds with acid Particles.

The third Particular proved by Experiments entirely agrees with Sir *Iſaac Newton*'s Reaſoning from the ſame Experiments, which I ſhall ſet down in his own Words. "Alſo "ſome ſulphureous Steams, at all "Times when the Earth is dry, "aſcending into the Air, ferment

" there with nitrous Acids, and " ſometimes taking Fire, cauſe " Lightning and Thunder and " fiery Meteors. For the Air a- " bounds with acid Vapours fit to " promote Fermentations, as ap- " pears by the ruſting of Iron and " Copper in it, the kindling of " Fire by blowing, and the beat- " ing of the Heart by means of " Reſpiration." *Opt. p.* 355.—— " And the Cauſe of Fermentation, " *which is an Acid*, by which the " Heart and Blood of Animals are " kept in perpetual Motion and " Heat." *Opt. p.* 375.

But this Author ſays, p. 75. *'Tis well known, that all Fluids, Acids as well as others, excepting Oil, will extinguiſh Fire, and that there is nothing in Nature but Oil that Fire can feed upon; for when the volatile and fixed Oil of any combuſtible Subſtance is conſumed and evaporated, the Fire*

can act no longer upon what remains, how much soever it may be assisted and supply'd with Air: Acids will check and extinguish Fire sooner than common Water, and any acid Vapour in the Air is more suffocating and destructive than any common watry Vapour and Fume. I grant that Fire and Flame cannot subsist without oily and sulphureous Particles, neither can they subsist without an Acid; for there was an Acid in all the Mixtures of the Experiments under the third Head: So that by those Experiments both an Acid and an Oil are necessary to the Production and Preservation of Fire and Flame. But to go on, he says, *that all Fluids, Acids as well as others, except Oil, will extinguish Fire.--And that Acids will check and extinguish Fire sooner than common Water.* And what then? will it from thence follow, that a nitrous Acid cannot when mix'd with some Oils

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in a certain Proportion produce Fire and Flame? By no means. For it has been found by Experiments, that if two Parts of compound Spirit of Nitre be poured on one Part of Oil of Cloves or Caraway Seeds, or of any ponderous Oil of vegetable or animal Subſtances, and particularly Oil of human Blood, or Oil of Turpentine thickened with a little Balſam of Sulphur, the Liquors grow ſo very hot in mixing, as preſently to ſend up a burning Flame. *Opt. Newt. p.* 353. *Phil. Tranſ. N.* 213. *p.* 200. And therefore, this acid Spirit muſt be allow'd to have a Power of producing Heat and Flame when mixed with certain oily and ſulphureous Subſtances in a certain Proportion: And ſo likewiſe may the nitrous Acid of the Air have a Power of preſerving Fire and Flame in ſulphureous and unctuous Subſtances when kindled, and of keep-

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ing up a gentle Heat in the Blood of Animals by mixing with it in the Lungs, and fermenting with its oily Parts; and that in fact it does ſo, the Experiments by me alledged have fully proved.

And I am ſtill farther convinced of the Neceſſity of allowing an Acid in the Air to preſerve the Life of Animals, when I conſider the Inſufficiency of all other Accounts of *Reſpiration.* As to the Uſe aſſigned to the Air by this Gentleman, namely, *that it ſerves as a proper exhaling Medium to receive and carry off thoſe copious Diſcharges of humid Effluvia or moiſt Vapour, which all living Creatures, and all combuſtible Matter under the Action of Fire, are inceſſantly emitting and throwing out;* I muſt beg leave to tell him, that this is an old trite Hypotheſis, without any the leaſt Foundation from Reaſon and Experiments. For Va-

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pours and Exhalations are not thrown off from humid Bodies by any Virtue in the Air, but by the repulsive Powers of their Particles, when by the Action of Heat, they are once separated from the Bodies, and are got beyond the Spheres of their Attractions and of the Attractions of one another. For this repulsive Power will carry off the separated Particles, as well *in vacuo* as in the open Air.

I could have wish'd Dr. *Morgan* had considered my *Animal Oeconomy* with a little more Temper as well as Care, and then I am satisfied he would have saved both himself and me some Trouble. It is however some Satisfaction to me, that he has given me an Opportunity of publickly declaring my self,

Sir, Your most Obliged,

July 12. 1735. *Humble Servant,*

BRYAN ROBINSON.

FINIS.

ERRATA.

PAGE 10. *l.* 5. *for* If A, *read* If a. *p.* 32. *l.* 11. *after* Water, *read* However I will grant that F is ever as D'H, and accordingly consider the Consequences he draws from it. *p.* 33. *l.* 3. *del.* ing.